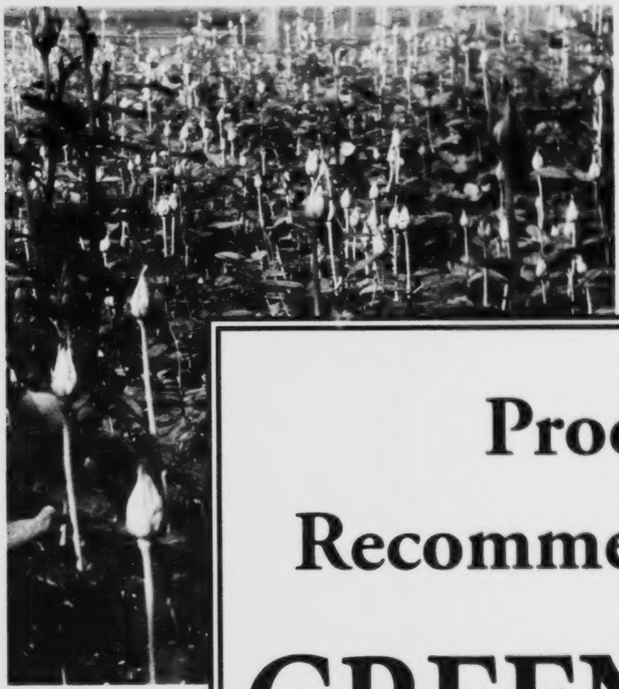

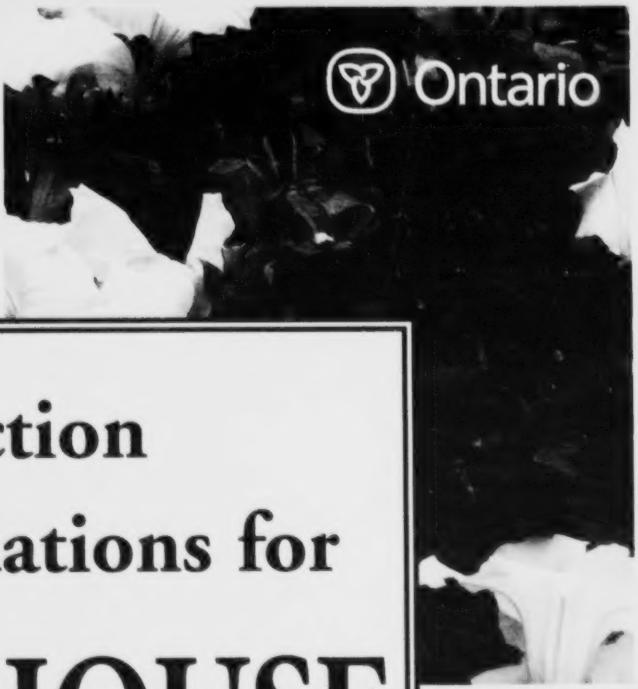

Ontario

Production Recommendations for GREENHOUSE FLORICULTURE

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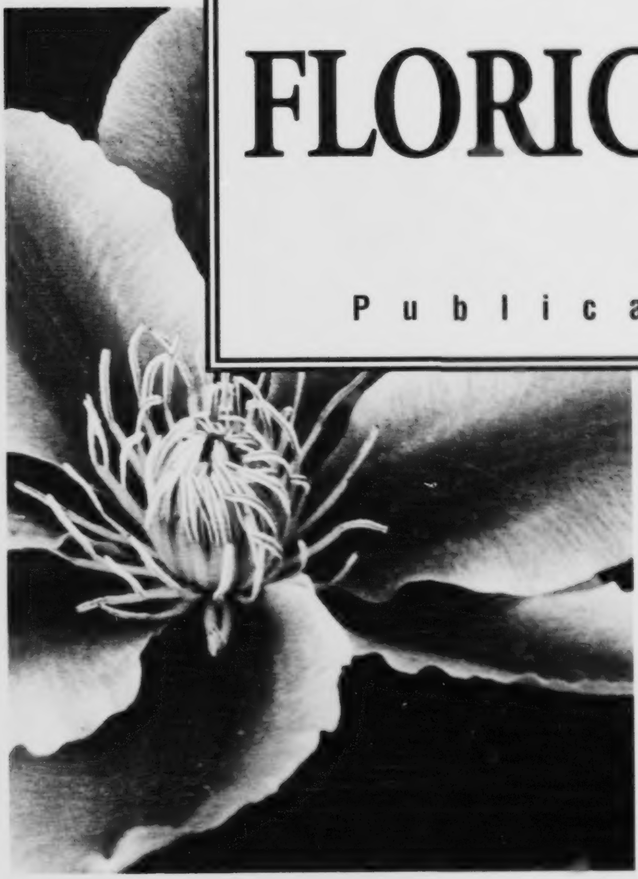
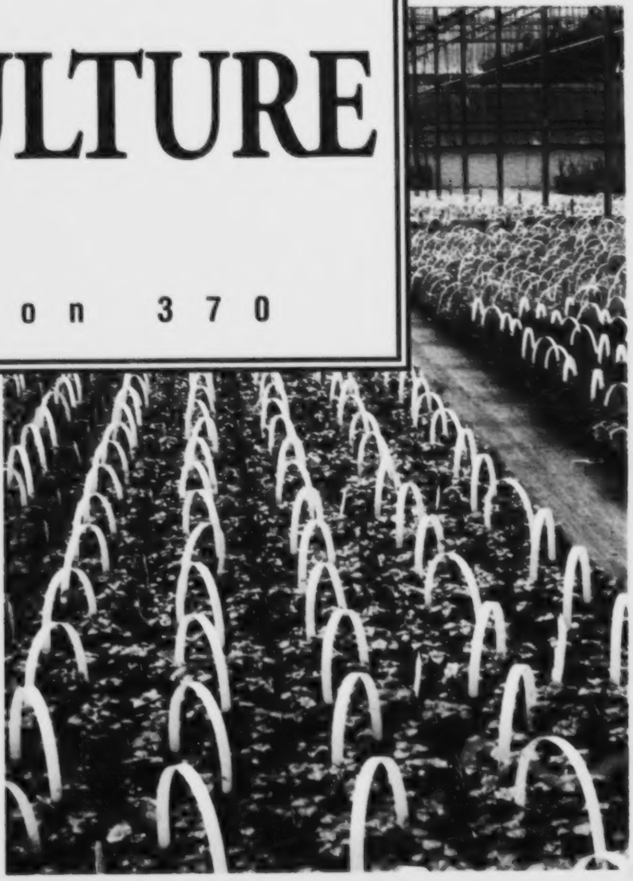




MINISTRY OF AGRICULTURE, FOOD AND RURAL AFFAIRS

Discard old editions of this publication. Each year the appropriate sub-committee of the Ontario Pest Management Research and Services Committee reviews the pesticides listed in this publication. To the best knowledge of the committee, at the time of printing, the pesticide products listed in this publication were:

- federally registered
- classified by the Ministry of the Environment as of June 2006.

The information in this publication is general information only. The Ministry of Agriculture, Food and Rural Affairs does not offer any warranty or guarantee, nor does it assume any liability for any crop loss, animal loss, health, safety or environmental hazard caused by the use of a pesticide mentioned in this publication.

This publication lists a number of brand names of pesticides. It is neither an endorsement of the product nor a suggestion that similar products are ineffective.

The Pesticide Label

Consult each product label before you use a pesticide. The label provides specific information on how to use the product safely, hazards, restrictions on use, compatibility with other products, the effect of environmental conditions, etc.

The pesticide product label is a legal document. It is against the law to use the product in any other way.

Federal Registration of Pesticide Products

The Pest Management Regulatory Agency (PMRA) of Health Canada registers pesticide products for use in Canada based on following an evaluation of scientific data to ensure that the product has merit and value; and the human health and environmental risks associated with its proposed use are acceptable.

1. **Full Registration**
   Pesticide registrations are normally granted for a period of five years, subject to renewal.
2. **Temporary Registration**
   Temporary registration may be granted for a period not to exceed one year, where the registrant agrees to produce additional scientific or technical information, or the pesticide is used for emergency control of a serious pest outbreak.

Maximum Residue Limits

Health Canada has established maximum residue limits (MRLs) for pesticides. Processors or retailers may demand more restrictive limits. Growers should seek advice of their intended market to determine if more restrictive limitations apply. Keep accurate and up-to-date records on pesticide use in each crop.

Supplemental Labels

You MUST obtain a supplemental label and follow all the label directions when PMRA approves new uses for a registered pesticide that do not appear on the current label.

Examples of when you must use a supplemental label include:

- **Temporary Registrations for Emergency Use**
- **Minor Use Label Expansion**.

You can obtain a copy of a supplemental label from the pesticide manufacturer or pesticide vendor, the grower association that sponsored the emergency registration or minor use, from OMAFRA or PMRA's Pest Management Information Service.

For more information on the federal registration status check the PMRA Web site at *www.hc-sc.gc.ca/pmra-arla* or call 1-800-267-6315.

Regulation of Pesticides in Ontario

The Ministry of the Environment is responsible for regulating pesticide sale, use, transportation, storage and disposal in Ontario. Ontario regulates pesticides by placing appropriate education, licensing and/or permit requirements on their use, under the *Pesticides Act* and Regulation 914.

All Pesticides must be used in accordance with requirements under the *Pesticides Act* and Regulation 914. The act and Regulation are available on the e-laws website at *www.e-laws.gov.on.ca* or call Publications Ontario Toll-Free number: 1-800-668-9938 or 416-326-5300.

Classification of Pesticides

The Ontario Pesticides Advisory Committee (OPAC) is responsible for reviewing and recommending to the Ministry of the Environment, the placement of pesticide products into one of six schedules used to control sale and use. Once approved by the Ministry of the Environment, classified products are posted on the OPAC website: *www.opac.gov.on.ca*. For more information call OPAC at 416-314-9230.

Certification and Licensing

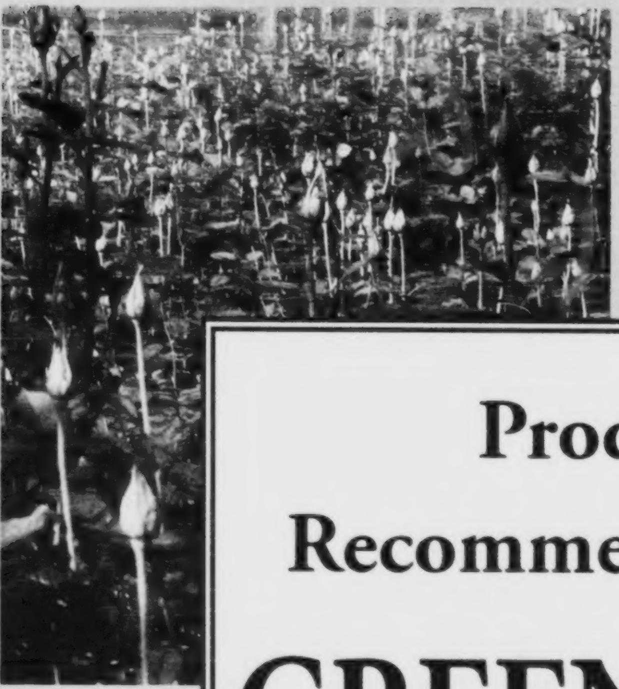
Growers and their Assistants

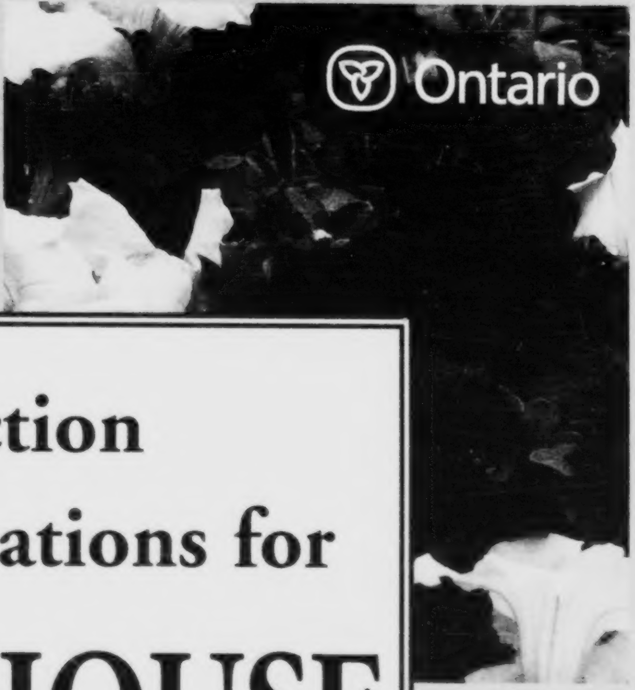
For information about certification for growers and training for assistants check the Ontario Pesticide Education Program website: *www.ridgetownc.uoguelph.ca/opep/* or call 1-800-652-8573.

Commercial Applicators and their Assistants

For more information about exterminator certification and licensing and technician training check the Ontario Pesticide Training & Certification website at *www.ridgetownc.uoguelph.ca/optc* or call 1-888-620-9999.

Cette publication est aussi disponible en français.





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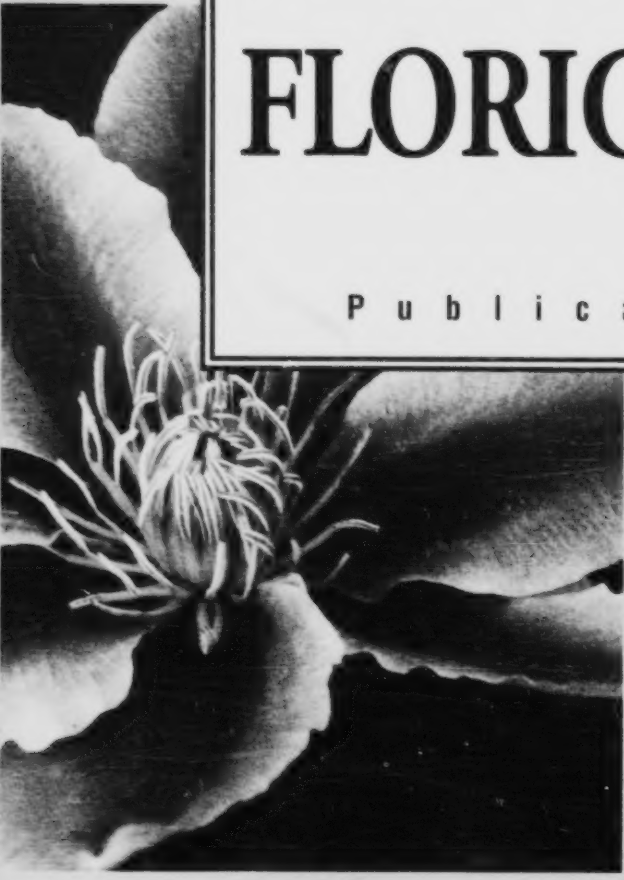

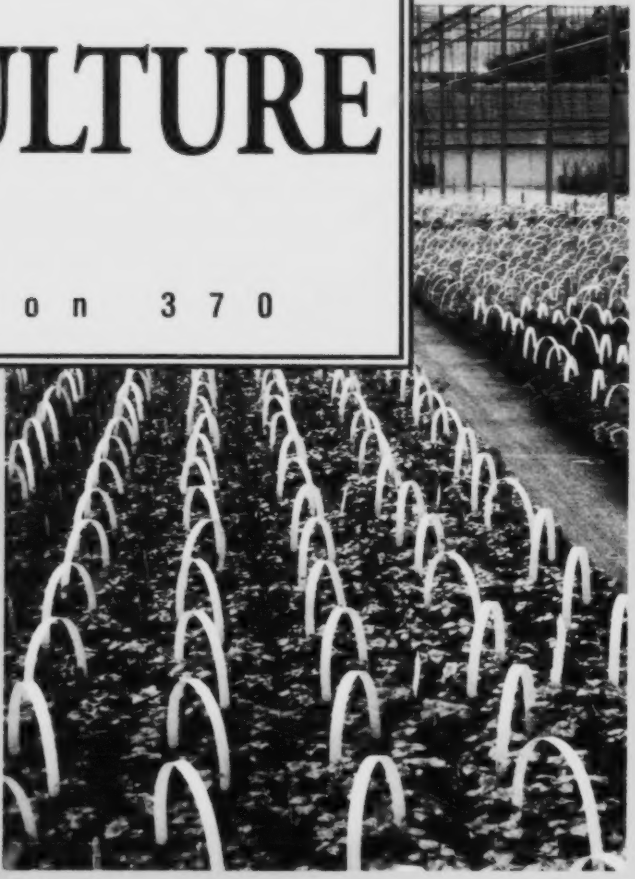

MINISTRY OF AGRICULTURE, FOOD AND RURAL AFFAIRS

Be Aware of Ontario's *Nutrient Management Act* and Other Legislation

The provincial *Nutrient Management Act* (NMA) regulates the storage, handling and application of nutrients that could be applied to agricultural crop land. The objective is to protect Ontario's surface and groundwater resources.

Please consult the regulation and protocols for the specific legal details. This publication is not meant to provide legal advice. Consult your lawyer if you have questions about legal obligations.

For more information on the NMA, call the Nutrient Management Information Line at 1-866-242-4460. E-mail: nman@omafra.gov.on.ca or visit the website: *www.omafra.gov.on.ca*.

Publications and Factsheets are continually being updated, so please ensure that you have the most recent version.

Need technical or business information?

Contact the Agricultural Information Contact Centre at:
1-877-424-1300 or ag.info@omafra.gov.on.ca

Looking for greenhouse floriculture production recommendations on the Internet?

www.omafra.gov.on.ca

It's one-stop shopping for factsheets, articles and photos regarding the production and management of Ontario's greenhouse floriculture crops.

Acknowledgements

The recommendations in this publication have been prepared in consultation with:

- Ontario Pest Management Research & Services Committee
- Ontario Horticultural Research & Services Committee
- Ontario Soil Management Research & Services Committee
- Ontario Weed Committee

and personnel of:

- Crop Technology, OMAFRA
- University of Guelph
- Ontario Ministry of Environment and Energy
- Crop Life Canada

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1. Precautions with Pesticides

Pesticide Regulations

Report all major spills, fires or thefts involving pesticides to the Ontario Ministry of the Environment at 1-800-268-6060. (Regulation 914, s. 29)

Pesticide Schedules in Ontario

The Ontario Ministry of the Environment reviews each pesticide product offered for sale in Ontario and classifies it into one of six groupings called Schedules.

Sch.	Who Can Use It	Pesticide Characteristics*
1	• licensed applicator • certified grower • only with approved permit unless exempt	• **very toxic** and/or • very persistent and/or • highly mobile
5	• licensed applicator • certified grower • assistant agriculturist under supervision	• **very toxic** and/or • very persistent and/or • highly mobile • less toxic or less persistent alternative not available
2	• licensed applicator • certified grower • trainee or technician under supervision (some restrictions apply) • assistant agriculturist under supervision	• **toxic** and/or • persistent and/or • moderately mobile
3	any person	• **moderately toxic** and/or • moderately persistent and/or • slightly mobile
4	any person	• **low toxicity** • non-persistent • non-mobile • containers <1 kg or <1 L
6	any person	• **low toxicity** • non-persistent • non-mobile • containers >1 kg or > 1 L

* Biological persistence and mobility in the environment as expected under normal use conditions in Ontario.

Certification and Training Requirements

Only certified growers, licensed exterminators or those that hold a special purchase and use permit may buy and use Schedule 1, 2 or 5 pesticides. Assistants may also use Schedules 2 and 5 pesticides if they are trained and supervised as required.

Pesticide Certification for Ontario Farmers

Regulation 914 of the *Pesticides Act* requires that agriculturalists (growers) be certified to buy and use Schedules 1, 2 or 5 pesticides on land they farm. To become certified, agriculturalists must:

- be at least 16 years of age
- attend the Grower Pesticide Safety Course (GPSC) and successfully complete the examination
- must fall into one of the following two categories and sign the following declaration on the GPSC application form:
  - "I am a farmer (grower) or farm employee. I currently use land that is classified as farmlands property under the Ontario *Assessment Act* for agricultural or forestry production."

    or

  - "I use land that is not assessed as farmlands property under the Ontario *Assessment Act*, but I am involved in the application of pesticides for the purpose of agricultural or forestry production. The agricultural or forestry commodity being produced is for market and not solely for consumption by me and members of my household. The agricultural or forestry production is not done as a hobby or for recreational purposes."

Training for Agricultural Assistants Using Schedule 2 or 5 Pesticides

All assistants must have formal pesticide safety training, recognized by the Ministry of the Environment, before they can handle or use Schedule 2 or 5 pesticides under the supervision of a certified grower.

This applies to all assistants, including family members, farm employees and seasonal workers.

Trained assistants do not have to write an exam.

Trained assistants must be at least 16 years of age.

There are two training options for assistants. Assistants can:

- attend a Grower Pesticide Safety Course and not write the certification examination (an examination is not required), or
- attend an on-farm training session presented by a qualified trained assistant instructor

For more information and a listing of Grower Pesticide Safety Courses session dates and locations, check the Ontario Pesticide Education Program website at *www.ridgetownc.uoguelph.ca/opep*.

To register for a Grower Pesticide Safety Course anywhere in Ontario or for information about trained assistants:

- Toll-free: 1-800-652-8573
- Fax: 519-674-1589
- E-mail: opep@ridgetownc.uoguelph.ca

Certification and Licensing for Commercial Pesticide Exterminators

For updates to training requirements under Regulation 914 of the *Pesticides Act*, refer to the Ministry of the Environment website at *www.ene.gov.on.ca* or phone 1-888-565-4923.

Anyone who applies pesticides as a business must be a licensed exterminator. This includes farmers who custom apply pesticides for other farmers and charge a fee for this service. Licensed exterminators who are self-employed must hold an operator licence as well as the appropriate exterminator licence. Exterminator licences are valid for five years.

Licensed exterminators must:

- successfully complete a home-study course and certification exam through Ridgetown College, University of Guelph, and
- apply to the Ministry of the Environment (MOE) to obtain an exterminator licence, provide proof of certification (letter of successful completion of the exam(s)) and a fee

Training for Technicians Working as Assistants to Licensed Exterminators

Assistants to licensed exterminators must become technicians to mix, load or apply all Schedule 3, 4 and 6 pesticides and most Schedule 2 pesticides (some restrictions apply), under the indirect supervision of a licensed exterminator. Technicians cannot mix, load or apply Schedule 1 or 5 pesticides. Technician cards are valid for two years.

Technicians must:

- complete an MOE–approved academic course and exam, and
- complete practical training with a licensed exterminator

For more information about certification and licensing requirements for licensed exterminators and training for technicians, contact Ontario Pesticide Training & Certification:

- Toll-free: 1-888-620-9999
- Fax: 519-674-1585
- Website: *www.ridgetownc.uoguelph.ca/optc*

Fumigants

Agriculturists who use methyl bromide plus chloropicrin or aluminum phosphide to fumigate greenhouses, vaults, warehouses and grain storages must obtain a permit issued under Ontario's *Pesticides Act*. To apply for a permit, contact the local Pesticides Officer with the Ontario Ministry of the Environment.

General Precautions

Always read the label:

- before you buy a pesticide

- before you begin to use a pesticide

- before you store a pesticide or dispose of it

Learn about the health hazards and toxic properties of the pesticide you are using. Consult the product label, Material Safety Data Sheets (MSDS) or manufacturer for this information. Check the company websites for MSDS information.

Protection When Using Pesticides

Tell someone where the work is taking place, what pesticides are being handled and how long the job is expected to take.

Post emergency numbers, including the Poison Information Centre and Spills Action Centre near all telephones.

Keep a list of the names and the *Pest Control Products (PCP) Act* Registration Numbers of all the pesticides handled. It's a good idea to keep a file of the pesticide label booklets for all the products used. Ensure that co-workers and family members know where this list or file is in case of an accident.

Have plenty of clean water, soap and paper towels—and an extra set of gloves and coveralls—nearby at all times in case pesticide contaminates clothing or skin.

Wear the correct protective clothing and equipment and be sure that all items are clean and in good repair before putting them on.

Never smoke, chew tobacco, eat or drink when handling pesticides. Never carry tobacco or food in clothes—and never leave tobacco, food or beverages in areas where handling or storing pesticides.

Change clothes and wash hands and face before eating, drinking or smoking.

Wash hands before using the toilet, as well as after. The skin in the groin area absorbs pesticides very easily.

When using fumigants:

- Remove livestock and poultry that are in the same building.
- As a safety precaution, have someone else who is wearing personal protective equipment help with the fumigation.

When using treated seed:

- Seed dressings or treatments are poisonous to people and livestock.
- Do not inhale the fumes or dust when treating or handling treated seed.
- Wear neoprene or nitrile gloves.
- Wash all residue of these chemicals from skin after finishing the treatment. Chemically treated seed is poisonous.
- Never feed surplus seed to livestock.
- Destroy all the bags that have held treated seed as recommended in *Disposal of Pesticides and Empty Pesticide Containers*, on page 11.

Protect Other People, Livestock, Pets, Water and Sensitive Crops

Buy and store only what is needed.

Prevent drift.

Keep pesticides out of water.

Clean up spills quickly and safely.

Dispose of containers and waste pesticide safely.

Human Health

Risks of Pesticide Use

Each time you handle a pesticide, you are at some risk. The amount of risk depends on two things — the toxicity of that pesticide and the person's exposure to it.

Risk = Toxicity × Exposure

Toxicity is a measure of how harmful or poisonous the pesticide is (for more information on pesticide toxicity, see Chapter 8, *Pesticide Activity and Toxicity*). There are two types of toxicity:

- **Acute toxicity** — the toxic response that results from a single exposure to the pesticide. The symbols and words on the front panel of a pesticide label give information about the acute toxicity.
  - **Lethal dose 50%** (LD_{50}) is a measure of acute toxicity. It is the dose (in mg of product per kg of body weight) that will kill 50% of the test animals within a stated period of time (24 hours to 7 days). Those products with low LD_{50} ratings are highly toxic. **Examples of products listed in this publication with a high acute toxicity include:**

Common (active) name	Trade name
dichlorvos	DDVP
endosulfan	Endosulfan, Thiodan, Thionex
nicotine	Nicotine Smoke Fumigator
pirimicarb	Pirliss

- ***Chronic toxicity*** — the toxic response that results from repeated exposures to small doses of a pesticide over a longer period of time. These toxic effects may not appear for months or years after exposure to the pesticide. The symbols on the label do not give information about the chronic toxicity of the product. Use protective clothing and equipment to help reduce exposure and the risk of chronic effects.

Exposure is a measure of the contact with the pesticide. Workers can be exposed to the pesticide in three ways:

- **Dermal exposure** occurs through skin or eyes. The amount and rate of pesticide that may be absorbed depends on several things, including:
  - skin condition. If the skin is moist, or if the person exposed has a rash, broken skin or scratches, pesticide will be absorbed more easily.
  - the part of the body that is exposed. Eyes, genital area, scalp and ear canals absorb pesticides at a higher rate than hands or arms. Eyes absorb pesticides at a rate of 100%.
- **Respiratory exposure (inhalation)** occurs when small spray particles, dust, gases or vapours are inhaled.
- **Oral exposure** occurs when a pesticide enters the mouth or is swallowed.

Cholinesterase Blood Tests

Organophosphorus and carbamate pesticides can affect people's nervous systems. These pesticides can change serum and red blood cell levels of an enzyme called acetyl cholinesterase. The body uses this enzyme to transmit messages through the nervous system. If cholinesterase levels fall, individuals experience such symptoms as trembling, twitching, blurred vision and breathing and heart difficulties.

People who use any of the pesticides listed below on a routine basis should have regular cholinesterase blood tests. A family doctor can arrange these tests, and they are covered by OHIP. Workers should have their first test before beginning to handle these pesticides to show their baseline (normal) cholinesterase level. During the spray season, workers who spray organophosphorus or carbamate insecticides regularly for several weeks should have a cholinesterase blood test every 7 to 10 days. If the worker's cholinesterase level drops to below one-half of his baseline level, he is showing signs of pesticide poisoning and must remove himself from exposure to these pesticides until his cholinesterase level returns to normal.

Common (active) name	Trade name
Acephate	Orthene
Bendiocarb	Trumpet
Dichlorvos	DDVP
Malathion	Malathion
Naled	Dibrom
Pirimicarb	Pirliss

First Aid

1. **Always protect yourself from injury first**. Don't become another victim. Always put on protective clothing and equipment before entering a contaminated area or handling a contaminated victim.

2. **Check to see if the victim is breathing**.

   If the victim is not breathing:

   - Straighten the victim's airway and check for breaths.
   - If the victim does not begin to breathe, administer artificial respiration until the victim begins to breathe on their own.
   - Do not contaminate yourself, especially if the victim has pesticide or vomit around the face or mouth. Use a faceshield airway with a one-way valve. Do not breathe the exhaled air from the victim.
   - Perform CPR if the victim's pulse disappears. You should perform CPR only if you are trained to do so.

   If the victim is breathing, but unconscious:

   - Place the victim in the recovery position (on the side with the head turned slightly to one side). If the victim vomits, try to keep the airway clear.

3. **Stop the exposure to the pesticide.** Move the victim away from the contaminated area. Remove all contaminated clothing. Use soap and water to wash any skin exposed to the pesticide.

4. **Check the Four Basic Facts:**
   - **Identify the pesticide**. Look for the label, container or leftover pesticide.
   - **Quantity** — How much product was the victim exposed to?
   - **Route of entry** — How did the pesticide enter the body? Did it enter through the mouth, skin/eyes or lungs?
   - **Time period** — How much time has passed since the victim was exposed to the pesticide and how long was the exposure? Were the symptoms immediate or did the poisoning occur as a result of using the pesticide over a longer period of time?

Don't waste time. If you can't answer these questions quickly, be ready to tell emergency personnel whatever you can.

5. **Call an ambulance or the Poison Information Centre**.

6. **Start the First Aid treatment appropriate for the route of entry**.

7. **Ensure the patient gets medical attention**. First aid is not a substitute for professional medical help.

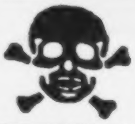
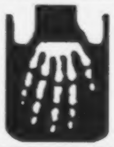
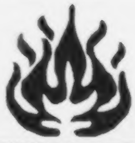
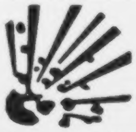
Emergency and First Aid Procedures for Pesticide Poisoning (See inside back cover)

If symptoms of illness occur during or shortly after handling a pesticide, go to a hospital. Take the pesticide label, MSDS sheet or pesticide container with you. Do not transport the container in the passenger compartment of the vehicle.

Read and Follow Pesticide Label Information

Know the Hazard Symbols and Words

Four important symbols and words show the potential hazards of pesticides.

Hazard Symbol	Signal Word
	Poison
	Corrosive
	Flammable
	Explosive

The hazard symbol always appears inside one of the shapes shown below. These shapes and their warning words tell you the degree of hazard of the pesticide. The greater the number of sides to the shape, the more hazardous the product.

	Warning Symbol	Signal Word
Triangular shape means low hazard (3 sides)	▽	Caution
Diamond shape means moderate hazard (4 sides)	◇	Warning
Octagonal shape means high hazard (8 sides)	⯃	Danger

Learn these symbols and words — they could save your life!

Check the label for special warnings about eye hazards and skin hazards. The front panel of the pesticide label may also contain warnings that caution the product is corrosive to eyes or is a skin or eye irritant.

TABLE 1–1. Re-entry Periods for Pesticides Registered for Greenhouse Use

4 Hours	12 Hours	24 Hours	48 Hours	96 Hours
• *Streptomyces griseoviridis* (Mycostop) • potassium bicarbonate (Milstop) • fenhexamid (Decree) • *Trichoderma harzianum* (RootShield)	• pyridaben (Dyno-Mite) • bifenazate (Floramite) • cyromazine (Citation) • kinoprene (Enstar II) • pymetrozine (Endeavor) • trifloxystrobin (Compass) • acetamiprid (Tristar) • deltamethrin (Decis) • Iprodione (Rovral) • metalaxyl (Subdue Maxx)	• bendiocarb (Trumpet) • myclobutanil (Nova)	• endosulfan (Endosulfan 400E. Thionex EC)	• captan (Supra Captan 80 WDG, Maestro 75 DF)

Re-Entry Periods

Re-entry period is the minimum amount of time that must pass between the time pesticide was applied and the time workers can go into the treated area without wearing personal protective equipment. If workers enter treated areas without wearing protective equipment too soon after pesticides have been applied, they may experience poisoning. Such poisoning can result from handling treated plants or from inhaling pesticide vapours.

Some pesticides have labels that carry a warning about working in treated crops. Follow the label recommendations. Otherwise, take note of the re-entry periods listed in Table 1–1. *Re-entry Periods for Pesiticides Registered for Greenhouse Use*, on this page, which shows specific minimum intervals between application of the greenhouse registered pesticide and work in the treated crop without protective equipment.

Total Number of Applications

Some product labels state the total number of applications of that pesticide that can be made during a growing season or a crop cycle. These limits are in place to address issues such as food residues, crop damage, soil residues or pest resistance.

Buffer Zones

Buffer zones are areas left untreated to protect an adjacent area, e.g., a pond, stream, sensitive crop, non-target crop, wetland, woodland etc. This may have implications for growers of outdoor flower crops.

Protective Clothing and Equipment

Choose and Wear the Appropriate Protective Clothing and Equipment

Make sure protective clothing and equipment:

- is what is needed for the job
- fits properly, and
- is clean and in good repair and working condition

The protective clothing and equipment workers need to wear depends on:

- **the pesticide being used** — read the precautions section of the label to know what to wear.
- **the job being done** — e.g., use more protection when handling concentrated pesticide or when mixing and loading a sprayer.
- **the type of application** — enclosed space or air-blast sprayer applications made with open tractors require more equipment.

All persons who work with pesticides need their own set of protective clothing and equipment. Consult the technical expert at the safety supply company to ensure the appropriate equipment is purchased and that it fits the user.

For all pesticides, always wear:

- Water-repellent hat, such as a hard hat or waterproof rain hat
  - – Sometimes the entire head and neck must be protected, for example, if applying pesticides in a

greenhouse, applying dusty formulations or using an air-blast sprayer. In these situations, wear a hood or hat that protects ear canals. Do not wear baseball-style or other cloth hats, which absorb pesticides and are not safe.

- Long pants and a shirt with long sleeves, or a coverall
  - Coveralls can be reusable or disposable. Reusable coveralls are normally cotton or polyester and should be tightly woven. Disposable coveralls should be designated for pesticide use.
  - Water-resistant coveralls are preferred because cotton, denim and cotton/polyester pants cling to the skin if they get wet, which increases the risk of dermal exposure.
- Chemical-resistant gloves (unlined)
  - Use neoprene or nitrile gloves (PVC), unless the label states otherwise. Do not wear rubber gloves as many pesticides can break down the rubber material. Wear gloves under sleeves with the top cuffed.
- Chemical-resistant boots (unlined)
  - Wear pant legs over boots to prevent pesticide from running down inside the boots.

Read the label. It will describe what extra protective clothing and equipment to wear. For some pesticides, workers may also need to wear:

- Goggles
  - Use safety goggles with indirect vents so that splashes do not enter the eye. Regular eye glasses don't provide complete protection. Never wear contact lenses when handling pesticides.
- Face shield
- Chemical-resistant apron
- Respirator
  - A respirator is a unit that covers the mouth and nose to prevent spray droplets, small particles and vapours from entering the lungs. A dust mask is not a substitute for a pesticide respirator. When you buy a respirator or replacement cartridges, use cartridges and pre-filters that protect against organic vapours. For more information about respirators, refer to the *Grower Pesticide Safety Course* manual, Ridgetown College, University of Guelph.

For fumigants:

- When you handle methyl bromide, do not wear gloves because these will trap gas next to the skin. Wear a full-face respirator with organic vapour canister or positive-pressure breathing apparatus. Some methyl bromide products require, by label, that self-contained breathing apparatus be worn at all times while using the product.
- When you handle aluminum phosphide, use cotton gloves and wear a full-face mask respirator with an acid-gas canister. However, in some instances, a respirator is required by the label. Note: the label is always the right place to find the appropriate safety equipment requirements.

When Working in Enclosed Areas

Canister Gas Masks

Canister gas masks are effective for protection against certain harmful gases, vapours and particulate matter. They are generally suitable for ventilated areas not subject to rapid change, but should never be used in confined spaces where oxygen deficiency and high gas concentrations may occur.

Self-Contained Breathing Apparatus

Air-purifying devices do not work in confined spaces where gas concentrations are unusually high. The lack of oxygen can prove fatal. Under these conditions, use an air supply provided by a self-contained breathing apparatus (e.g. Scott Air Pack).

Substances that produce hydrogen cyanide, methyl bromide, chloropicrin or phosphine can produce high gas concentrations and oxygen deficiency as can smoke generators, foggers that use highly toxic pesticides and some volatile sprays.

Other Protective Clothing

Wear other protective clothing in keeping with requirements listed on the pesticide label.

Working Conditions

It must be stressed that the label is the place to find the appropriate safety equipment requirements. Use the recommendations below as a guide, but check the label to be sure.

Use canister gas masks when the surrounding air contains low concentrations of toxic gases, vapours or particulate matter derived from soil-drench, granular, dust or foliar spray applications. Pesticides applied in this manner usually have moderate to low toxicity.

Use a self-contained breathing apparatus (e.g. Scott Air Pack) when you apply highly toxic pesticides. These can produce high concentrations of toxic gases, vapours or particulate matter, and a lack of oxygen, especially in an enclosed space (e.g., when fumigating grain).

If using fumigants or insecticidal smokes:

- During and after treatment, lock the building and post warning signs.
- Follow instructions on the product label in regard to aeration of treated buildings, warehouses, grain storage bins or other areas before letting anyone enter.
- Contact a safety supply company for recommendations.

Safety Supply Companies

Consult a safety supply company for help in selecting protective clothing and equipment. See Table 1–2. *Safety Supply Companies in Ontario Providing Protective Clothing and Equipment*, on page 9.

Care of Protective Clothing and Equipment

After completion of the spray operation, clean all protective clothing and equipment.

Never let children, pets or livestock come in contact with contaminated clothing or equipment. Also ensure that they cannot come into contact with the puddles of water that result when cleaning equipment.

Wash gloves with soap and water and then leave them on to remove other protective clothing and equipment.

Always remove protective clothing and equipment outdoors. If a granular pesticide was used, shake the clothing outdoors in a safe place. Be sure to empty pockets and cuffs.

Clothing that has been contaminated by spills of highly toxic or concentrated pesticide should be thrown out. Place clothing in a plastic bag and take it to a landfill site.

Coveralls and other spray clothing must be washed separately from other clothes. They should be washed after each use. After laundering, place them in a plastic bag and keep them separate.

With hands still protected by gloves, wash protective equipment. It is best to wash equipment outdoors. If the work area does not have an outside cleanup area, keep certain buckets just for equipment cleanup. Mark them and keep them in a special place. Wash the inside and outside of goggles, hat, boots and any water-repellent clothing in warm soapy water, rinse well and let air-dry.

Respirators

Remove the cartridges and prefilters from the respirator.

Discard cartridges, canisters and filter pads when breathing becomes difficult, when a pesticide taste or odour is noticed or at the interval set by the manufacturer.

Note the date the cartridge is first used.

Remove cartridges and filter pads from the face piece and store in clean, sealed plastic bags.

Wash the face piece in warm soapy water, rinse thoroughly and dry in a well-ventilated area. Air-drying prevents damage to the inlet and outlet valves.

Never use alcohol or other solvents for cleaning, as they will damage the rubber and plastic.

Rubber, Vinyl, or Plastic Boots and Gloves

To avoid getting pesticide on hands, wash the outside of boots and gloves with detergent and water before taking them off.

After removing boots and gloves, wash them inside and out with detergent and water, rinse them thoroughly and dry them in a well-ventilated area.

How to Wash Clothes Used for Spraying

Never mix spray clothing with household laundry. All clothing used for spraying must be stored and washed separately from other clothing. Wash spray clothing after each use. Remember to use chemical-resistant gloves to handle pesticide-contaminated clothing.

Presoak clothing before washing. Use one of three methods:

- hose off garments outdoors
- soak in separate tub or pail
- use the prewash cycle in an automatic washer

TABLE 1–2. Safety Supply Companies in Ontario Providing Protective Clothing and Equipment

3-M Canada Inc.	Occupational Health and Environmental Safety Box 5757 London, ON N6A 4T1	Tel: 519-452-6165 Toll-free: 1-800-364-3577 Fax: 519-452-4660
Acklands Grainger	90 West Beaver Creek Road Richmond Hill, ON L4B 1E7	Tel: 905-731-5516 Toll-free: 1-800-668-8989 Fax: 905-731-2798
Aearo Canada	7115 Tomken Road Mississauga, ON L5S 1X7	Tel: 905-795-0700 Toll-free: 1-800-387-4304 Fax: 905-564-5250
Dutch Industries "Protect-Air Cab Filter"	Huron Tractor Box 1300 Exeter, ON N0M 1S3	Tel: 519-235-1115 Fax: 519-255-1939
HAMISCO	3392 Wonderland Road London, ON N6L 1A8	Tel: 519-652-9800 Toll-free: 1-800-668-9800 Fax: 519-652-9661
DuPont Personal Protection	20 Ryan Place Box 1687 Brantford, ON N3T 5V7	Tel: 519-752-4369 Toll-free: 1-800-387-9326 Fax: 519-752-2161
Levitt-Safety (Eastern) Limited	2872 Bristol Circle Oakville, ON L6H 5T5	Tel: 905-829-3299 Toll-free: 1-800-668-6153 Fax: 905-829-2919
Mitt & Robe Co.	751 Norfolk Street North Simcoe, ON N3Y 3R6	Tel: 519-428-4050 Toll-free: 1-877-893-6565 Fax: 519-428-5142
MSA Canada Inc.	148 Norfinch Drive North York, ON M3N 1X8	Tel: 416-667-9400 Toll-free: 1-800-267-0672 Fax: 416-663-5908
Plant Products Co. Ltd.	314 Orenda Road Brampton, ON L6T 1G1	Tel: 905-793-7000 Toll-free: 1-800-387-2449 Fax: 905-793-9632
Safety Express	4060B Sladeview Crescent, Unit 2 Mississauga, ON L5L 5Y5	Tel: 905-608-0111 Toll-free: 1-800-465-3898 Tax: 905-608-0091
The St. George Company (Suppliers of Kasco Helmets)	20 Consolidated Drive P.O. Box 430 Paris, ON N3L 3T5	Tel: 519-442-2046 Toll-free: 1-800-461-4299 Fax: 519-442-7191

Place clothing directly into the washing machine. Wash only a few garments at a time. Do not wash with other family clothes.

Use hot water, the highest water level and the longest cycle with heavy-duty detergent. Wash as for heavily soiled clothing.

Wash clothing again.

After washing, hang outside (preferably in bright sunlight) until completely dry. Do not use a clothes dryer.

Clean the washing machine. Run the washing machine through one complete cycle using only detergent and hot water (no clothing).

Personal Hygiene

Always wash your hands before eating, drinking or smoking.

When finished for the day, take a bath or shower as soon as possible. The longer a pesticide remains on the skin, the greater the risk that it will be absorbed into the body.

Wash hair and under fingernails. Shower with lots of soap and water.

Always change into clean clothes.

Wear clean work clothes every day. A small spill on the previous day's clothes may seem unimportant, but wearing the same clothing again without washing it prolongs exposure and increases risk.

Protect the Environment

Protect Water Sources

Use an anti-backflow device to prevent back-siphoning when drawing water from wells, ponds, streams or other sources.

Mix pesticide and load the sprayer away from any water supply, including wells, ponds or streams.

Use buffer zones (untreated areas) when you apply pesticides to avoid contaminating surface water, wells, ponds and/or streams. Check the product label for specific buffer-zone distances.

Reduce and Manage Pesticide Spray Drift

For outdoor applications, spray only when winds are light to moderate (less than 11 km/h), however be aware that some labels specify lower wind speeds, such as 8 km/hr. If drift occurs because of the wind, stop spraying until the wind subsides. Do not apply pesticides if the wind is blowing towards susceptible crops or environmentally sensitive areas such as watercourses.

Read the product label for information regarding buffer zones, water volumes and recommended nozzles.

Use buffer zones around all watercourses and wells and neighbouring fields that contain sensitive crops. If the label does not state a specific buffer-zone distance, leave an untreated area of natural vegetation.

Select the recommended sprayer application rate (L/ha).

Select the correct nozzle. Where practical, use air induction/venturi nozzles. These nozzles significantly reduce drift when compared to conventional nozzles.

Select the correct nozzle-to-target distance.

Use spray plume protection (hoods, shrouds, screens and air curtains) where practical or available.

Use drift-reducing adjuvants in the spray tank as directed by the label.

Utilize wick weeders, instead of spraying, when possible.

For more information about spray drift consult the OMAFRA/Agriculture and Agri-Food Canada booklet *Best Management Practices—Pesticide Storage, Handling and Application* and the Ontario Pesticide Education Program (Ridgetown College) videos *How to Manage Spray Drift* and *Spray Drift Reduction through Air Induction*.

Prevent Bee Poisoning

While protection of bees is not relevant to most greenhouse flower growers, it is an important consideration for growers of outdoor flowers. Honeybees, as well as other bees and insects, are important pollinators of crops. Many crops also offer bees important sources of nectar for honey production.

If you choose to use insecticides for insect control, take these steps to prevent harming bees:

- Before you apply a pesticide, advise local beekeepers so they can move colonies out of the danger area. Contact the Provincial Apiarist at 1-888-466-2372 for a list of the beekeepers in the area.
- Do not spray any flowering crop on which bees are foraging. If you must apply insecticides, spray after 7 p.m. when the bees are not foraging. If this is not possible, spray before 7 a.m. Bees usually do not forage at temperatures below 13°C.
- Do not apply insecticide on windy days to prevent drift towards any nearby hives.
- When there is a choice, choose the product formulation that is less hazardous to bees. Dusts are more toxic than sprays. EC formulations are less toxic than WP formulations.
- Under the *Bees Act* it is an offence to spray in orchards while there is bloom on the trees.

Most organophosphate and carbamate insecticides are highly toxic to bees. Examples of insecticides used in crop production that are toxic to bees are listed in Table 1–3. *Relative Toxicity of Insecticides to Honeybees*, on page 11.

TABLE 1–3. Relative Toxicity of Insecticides to Honeybees

Trade Name	Active Ingredient
Group 1 – Highly toxic. Do not apply to flowering crops or weeds outside the greenhouse	
Intercept	imidacloprid
Avid	abamectin
Success	spinosad
Dyno-Mite	pyridaben
Pounce	permethrin
Decis	deltamethrin
Diazinon	diazinon
Cygon, Lagon	dimethoate
Imidan	phosmet
Malathion	malathion
Sevin	carbaryl
Group 2 – Moderately toxic. Apply only during late evenings or early morning*	
Tristar	acetamiprid
Pirliss	pirimicarb
Endosulfan, Thiodan	endosulfan

* Unusually low temperatures at time of application may cause insecticides to remain toxic up to 20 times longer than during warm weather. High temperatures in the early morning or late evening may extend active foraging by bees.

Read each pesticide label for specific precautions regarding bees.

Disposal of Pesticides and Empty Pesticide Containers

Triple or Jet Rinse Empty Pesticide Containers

Unrinsed pesticide containers are not really empty; they may still hold about 1% of the original amount of pesticide. Although this figure sounds low, it is still a hazard to humans, animals and the environment. To reduce the hazard, rinse each container three times as the spray tank is filling and add rinsate to the tank. Use either the manual triple-rinse technique, or a specially designed device for rinsing containers. Paper or cardboard containers are often strong enough to be rinsed. If possible, rinse these containers as well as plastic ones.

To Triple Rinse

1. Fill the empty container at least 10% full of the diluting material (usually water).
2. Cap, then shake or roll the container so the inside surfaces of the container are well rinsed.
3. Pour rinsings into the spray tank.
4. Repeat steps 1–3 twice more.

Remember to check the container after rinsing. Ensure that no pesticide has been left behind as a cake or paste on the bottom of the container.

Rinsing Devices

Rinsing devices use pressurized water to clean out the container. They are just as effective as triple rinsing but take less time. Follow the manufacturer's instructions.

How to Dispose of Empty, Triple-Rinsed Containers

Never re-use empty pesticide containers. They may be handy, but there is still some risk even if the containers are triple rinsed. Never give empty, rinsed containers to anyone, especially children. Dispose of them promptly.

Regulation 914 (section 27) of the *Pesticides Act* regulates how pesticide containers are to be disposed of in Ontario.

For Metal, Plastic or Glass Containers

Dispose of empty metal, plastic or glass containers that have held a Schedule 1, 2, 3*, 5 or 6* (*non-domestic) pesticide:

- Triple rinse or jet rinse using clean water, or another appropriate solvent and either:
  - take them for recycling to a Pesticide Container Depot, or
  - take them to a licensed waste disposal site.
- Once containers are properly rinsed, puncture them so they cannot be used again and to ensure the rinse water is out of the container.

It is often more convenient to store empty, rinsed containers until there are enough to make a trip to the recycling Pesticide Container Depot or the waste disposal site. If you store containers, make sure they have been rinsed and punctured to prevent re-use and store them in a dry, safe place, such as the pesticide storage area, until you can dispose of them properly.

Recycling

The Ontario Pesticide Container Recycling Program is available to growers and commercial applicators. Through this program, clean, triple-rinsed, plastic/metal pesticide containers (up to 23 L for plastic and 20 L for metal) can be returned to Pesticide Container Depots located throughout the province. To locate the closest Pesticide Container Recycling Depot, call the Ontario Pesticide Education Program at 1-800-652-8573.

For Paper and Cardboard Containers

A paper or cardboard container that has been used to hold a Schedule 1, 2, 3*, 5 or 6* (*non-domestic) pesticide (including fungicide-treated seed) must be disposed of by:

- triple rinsing or jet rinsing (if possible) using clean water and either:
  - burning, (if allowed by municipal bylaws) in circumstances that persons and animals are kept out of any smoke produced and any smoke is directed away from buildings, highways, roads or outdoor areas frequented by the public, or
  - taking it to a licensed waste disposal site.

Paper or cardboard containers are often rigid enough to withstand rinsing. If possible, triple rinse these containers while filling the tank, then burn the containers in an isolated area of the farmland (if allowed by municipal bylaws).

Be very careful around the smoke. It may contain toxic fumes from the burning pesticide. Be certain there is no chance a person or animal may breathe this smoke. Ensure the smoke does not drift towards buildings, roads or any public outdoor areas.

Pesticide containers can also be taken to a local waste disposal site in the same way as metal, plastic or glass containers. If immediate disposal is impossible, keep containers in a secure place such as the pesticide storage area.

Unwanted Pesticides

For excess pesticides, dispose of them safely.

Contact the supplier. It is sometimes possible to return unused pesticide if it is still in its original container.

If the product cannot be used as shown on the label, the Ministry of the Environment requires that excess pesticide be disposed of by licensed waste haulers to a licensed waste disposal site. Look in the Yellow Pages of the telephone directory under "Liquid Waste Removal."

Watch the local paper for Municipal Waste Collection Days or contact the municipality. If the municipality has no waste collection days, encourage it to sponsor such an event. On these days, turn over surplus pesticide concentrates (maximum 25 L) for disposal. Check whether agricultural pesticides are accepted.

Surplus Spray Mix

The best way to deal with surplus spray mix is to prevent the production of it in the first place with careful planning and calculations. However, if excess spray does exist after application, then the best way to dispose of it is to find other fields that require an application of this pesticide. Before spraying, check the label to make sure the pesticide is registered for use on that crop.

If it is impossible to find another field to spray, dilute the remaining spray mix by adding 10 parts of water for each 1 part of spray mix. This diluted solution can be safely applied to the treated area as long as you do not exceed the pesticide rate recommended on the label. Be sure to check the label for any restrictions about crop rotation, days to harvest, or surplus spray mix disposal.

Never respray the treated field with undiluted spray mix. Spraying an area twice will double the recommended pesticide rate. This may cause illegal pesticide residues in the harvested crop or harmful residues in the soil that can cause crop damage.

Soluble Packaging Options

Choose soluble packages that dissolve in the spray tank to reduce container disposal. Water-soluble packaging is used for dry flowable and wettable powder formulations of pesticides and is available under names such as Clean Pak, Solupak and Toss-N-Go. In most cases, the water-soluble packaging material is PVA (poly vinyl alcohol). This material dissolves completely when added to the water in the sprayer tank according to instructions.

Read all labels and instructions carefully. For more details contact the pesticide vendor.

Keep soluble pouches dry until adding them to the spray tank.

- Do not handle pouches with wet hands or wet gloves.
- Do not remove pouches from the outer package until ready to add them.
- Always reseal the outer package to protect the remaining pouches from moisture.

Mixing Soluble Pouches

Consult product labels for specific mixing instructions for each product.

Fill the spray tank one-quarter full of water and have the agitator running. Then add the water-soluble pouches to the tank.

Most pouches dissolve completely within 5 minutes, depending on the water temperature and the degree of agitation.

As the tank continues to fill, add any other compatible pesticides.

Do not add:

- a pesticide that is incompatible with the PVA packaging material. The PVA material is not soluble with summer-type oils (e.g., Superior Oil).
- any material containing boron (e.g., Solubor), chelated micronutrients or water-soluble fertilizers. This combination is likely to cause a sticky, insoluble substance in the tank. If you apply boron, chelated micronutrients or water-soluble fertilizers, completely empty and rinse the spray tank before you use any product packaged in PVA.

Storing Pesticides

Ontario's *Pesticides Act* and its Regulation 914 give storage requirements for storage facilities. See Table 1–4. *Pesticides Act Storage Requirements*, on this page. The storage requirements depend on which Schedules of pesticides are stored.

TABLE 1–4. *Pesticides Act* Storage Requirements

	Schedule 3, 4 & 6	Schedule 2	Schedule 1 & 5
No contact with food or drink	◆	◆	◆
Not impair health/ safety	◆	◆	◆
Clean and orderly manner	◆	◆	◆
Warning signs posted on storage buildings	◆	◆	◆
Warning signs posted on unattended vehicles	◆	◆	◆
Emergency telephone numbers posted	◆	◆	◆
Ventilated to outside		◆	◆
Limited access (locked)		◆	◆
No floor drain		◆	◆
Safety equipment available		◆	◆
Area used exclusively for pesticides			◆

See also OMAFRA Factsheet, *Pesticide Handling Facilities*, Order No. 94-037.

Pesticide Spills

Protect yourself before beginning to clean up any spill. Clean up spills immediately.

In the case of minor spills:

- For liquids, cover the spill with a thick layer of absorbent material such as kitty litter, vermiculite or dry soil. Sweep or shovel the material into a waste drum.
- For powders and granulars, sweep or shovel the material into a waste drum.

In the case of a major spill:

- Remove any people or animals from the spill area.
- Stop the spill from spreading.
- Do not let the pesticide enter any watercourse.

If a pesticide spill is abnormal in quality or quantity, you must notify the Ministry of Environment, Spills Action Centre at 1-800-268-6060 (24 hours a day, 7 days a week) and the municipality.

If you are unsure whether or not to report it – report it!

For information on preventing spills see OMAFRA Factsheet, *Ways to Avoid Pesticide Spills*, Order No. 96-025.

2. Water, Growing Media and Crop Nutrition

Introduction

Living plants consist of water (≈90%), organic matter (4%–10%) and minerals (15%). The organic matter is produced by photosynthesis in the green leaves, while water and minerals (plant nutrients) are generally taken up by the roots growing in soil or soilless substrate and transported within the plant through specialized tissue (the veins of the plant) called the xylem. Most water taken up (≈90%) is lost through the leaves and into the air in a process called transpiration, while smaller amounts (≈1%) are used for photosynthesis or as plant constituent (≈9%). Carbohydrates (sugars and starches) are produced by photosynthesis and distributed within the plant by tissue called the phloem, generally in a downward direction.

Water

Water is one of the most important compounds for growing a crop, yet it is often the most neglected. Water serves as a medium in which chemical processes, such as nutrient uptake and photosynthesis, take place and acts as a coolant through transpiration for both the crop and its environment. Both quantity and quality of water are critical for a good crop.

Uptake

Water uptake can be divided into active and passive uptake. Active uptake requires energy (from respiration in the roots) by increasing the nutrient concentration within the roots and creating suction on the water outside the root through osmosis.

The passive uptake of water through the roots of the plant begins with water transpiration from the leaves through openings called stomata. Water vapour moves from areas of high water vapour pressure in the leaves through the stomata to areas of lower pressure outside the plant. Under conditions of high humidity, less water vapour will be lost from the plant because there is a higher water vapour pressure outside the plant (resulting in a lower pressure difference between the inside of the leaf and the surrounding air) than there is when the humidity is lower. This process begins a chain reaction whereby water is drawn up through the xylem to replace that lost through the leaves. Consequently, water in the soil is drawn in through the root hairs following the same gradient. Water uptake into the roots is also dependent on the moisture levels in the soil and the salt concentration in the soil. All three factors — relative humidity in the air, soil moisture and salt concentration in the soil solution — affect water uptake.

Quantity

Water requirements for a crop can vary between 0.1 and 7 L of water per square metre of greenhouse per day, of which 90% is required during daylight hours. This varies according to plant species, plant size, relative humidity, solar radiation, temperature/heating and rate of ventilation. When sizing irrigation equipment (lines, pumps, nozzles) it is recommended that a minimum of 1 L/m^2/hour be used as a base requirement for capacity sizing of the irrigation lines and system. The total annual water requirement for a year-round greenhouse operation with a high leaf area index (e.g. vegetables) in a recirculating system exceeds the Ontario annual precipitation by about 25%–35%. This means that rainwater collected from the greenhouse roof alone does not fulfill the annual requirements. Water is particularly critical during the summer. Greenhouse operations using a large daily volume taken from surface or groundwater sources must conform to Ministry of Environment regulations regarding the usage.

Permit to Take Water

www.ene.gov.on.ca/envision/water/pttw.htm

Permit to Take Water

The taking of water in Ontario is governed by the *Ontario Water Resources Act* (OWRA) and the *Water Taking and Transfer Regulation* (O.Reg.387/04). Section 34 of the OWRA requires anyone taking more than a total of 50,000 litres of water in a day from a lake, stream, river or groundwater source including spring-fed ponds, to obtain a permit from the Ministry of the Environment (MOE) to take water. All permit holders are required to collect and record the volume of water taken daily and report this data annually to the MOE. Water conservation is an important part of the MOE's Permit to Take Water program. Conservation measures being taken or being proposed must be documented when making an application. For further information, refer to the *Permit to Take Water Manual*, the *Guide to the Permit to Take Water Application Form* and other related factsheets online at *www.ene.gov.on.ca/envision/water/pttw.htm*.

Managing Water Use

Efficient use of water as a resource should be a key best management objective of every greenhouse operation. Closed or re-circulating nutrient systems are inherently the most efficient but are not suitable or cost effective for all cropping systems. For growers who use open irrigation systems, there are a number of approaches to consider. For example, conversion to low volume drip emitters for potted flowering crops and to low volume drip tape for soil-grown cut flowers are relatively low cost considerations to reduce the amount of water and fertilizer used and potentially leached from the root zone of the crop. Greater integration of the growing environment (light, temperature and humidity) with respect to crop and crop age can reduce water and fertilizer usage. Consideration should be given to directing tile drain leachate into an irrigation pond, an artificial wetland or vegetative filter strip before discharging to the environment. Both federal and provincial legislation protect water courses and aquatic organisms from harmful discharges.

Quality

In addition to having a plentiful and reliable supply of water, the quality must also meet certain criteria, the most important of which are:

- the concentration of suspended particulates, which can affect irrigation equipment or residue on the foliage with overhead watering
- the amount of dissolved chemicals/elements, which can impact on plant growth and nutrition

It is the second of these (the amount of dissolved chemicals) that causes growers the most concern. The specific requirements for water quality depend on several factors:

- The type of growing/irrigation system to be used. Is it a once-through or recirculating top irrigation system (soil or substrate), or a recirculating system (sub-irrigation system for potted plants) or nutrient film technique?
- Water quality standards must be higher for a recirculating system as certain ions may accumulate in the solution and there is the increased potential for spread of root diseases.
- Good drainage for excess water in case the need for leaching arises.
- The type of crops to be grown and their specific needs or sensitivities for particular elements such as boron, fluoride, zinc, etc.

In situations where crops are being irrigated from the top (overhead) with no recirculation, a simple water analysis will suffice to determine water quality. This analysis includes electrical conductivity (EC), hydrogen ion (pH), sodium (Na^+), chloride (Cl^-), and sulphate (SO_4^{2-}) concentration. For sub-irrigation, or in recirculating systems, a complete water analysis including bicarbonates (HCO_3^-) and micronutrients such as iron (Fe^{2+}/Fe^{3+}), boron (B), zinc (Zn^{2+}), manganese (Mn^{2+}) and copper (Cu^{2+}) is recommended.

Electrical Conductivity (EC)

The EC is a measurement of the total amount of ions (or actually total ionic charge) in the solution. The total ionic charge is measured by an electrical conductivity (EC) meter and is often referred to as the total soluble salts. A high number of ionic charges results in a high EC. The EC measures the conductivity of a solution by means of two electrodes, each 1 cm^2 in size and 1 cm apart. It is expressed in millimhos/cm (mmho/cm) or milliSiemens/cm (mS/cm or dS/m) at the standard temperature of 25°C. Another way of referring to soluble salts is by the ionic concentration in equivalent weight per litre (eq/L or meq/L), which represents the amount of charge provided by all ions in solution.

To convert between eq/L and mS/cm:

- 1 meq/L ≈ 0.055 mS/cm ≈ 55µS/cm
- 1 mS/cm = 1,000 µS/cm ≈18.2 meq/L

where the 'm' represents milli (0.001 or 1 part per thousand) and the µ represents micro (0.000001 or 1 part per million).

Remember that an EC meter does not measure the concentration of specific ions but the total sum of all ionic charges. A high value indicates a high concentration of ions in solution and the more difficult it is for the plant to absorb water from this solution due to the increased osmotic suction. The EC meter should be calibrated on a regular basis with a standard solution with a known EC. For example, 0.01 M potassium chloride (KCl), made by dissolving 0.74 g KCl in 1 L water, has an EC of 1.4 mS/cm at 25°C. With repeated use of the meter, the EC reading becomes lower as the electrodes oxidize. Clean the electrodes by placing them in an acid solution (pH 1.0–2.0) overnight. If the EC meter is not temperature-corrected to 25°C, increase the measured values by 2% for each 1°C less than 25°C.

A general quality classification for water is given in Table 2–1. *Classification of Water Quality Based on Electrical Conductivity (EC) and Certain Specifications*. It is a modified version of Dutch and Ohio recommendations. Note that all conditions must be met in order to place a sample in a certain class.

TABLE 2–1. Classification of Water Quality Based on Electrical Conductivity (EC) and Certain Specifications

Class	E.C. (mS/cm)	Sodium (Na^+) (ppm)	Chlorides (Cl^-) (ppm)	Sulphates (SO_4^{2-}) (ppm)
1	<0.5	<30	<50	<100
2	0.5–1.0	30–60	50–100	100–200
3	1.0–1.5	60–90	100–150	200–300

Water quality of Class 1 is good for all irrigation purposes. Most water obtained from Lakes Erie and Ontario falls within this category. Use water belonging to Class 2 only in substrate and soil culture where adequate leaching can take place. Class 2 is unsuitable for a nutrient film technique and salt-sensitive crops grown in sub-irrigation systems. Class 3 is not recommended for salt-sensitive crops (e.g., primula, African violet, gloxinia), or crops grown in a limited root volume or recirculating systems. If the salt level exceeds 1.5 mS/cm, it is considered marginally suitable for greenhouse irrigation. In some cases, crops can be grown but yields may be reduced as a result. The toxic concentration for sodium (Na^+) is lower than that for chlorides (Cl^-) due to the fact that sodium has a tendency to be absorbed in soil or humus particles and accumulates in the soil/substrate. It may interfere with the uptake of potassium, calcium and magnesium. Chlorides have less tendency to accumulate in soil/substrate due to their negative charge. Some crops (e.g., cucumber, azalea) are chloride sensitive. Note that sodium levels in well water for most areas in Ontario are low, while sulphates can be relatively high due to the presence of gypsum in the aquifers. Most crops do not require more than 100 ppm of sulphates (33 ppm elemental sulphur) to meet their nutritional requirement for sulphur.

Why Measure EC?

Even though the EC measurement does not indicate which nutrients are present or in what quantity, it does provide an overall level of the nutrient status of the solution. A high EC means there are many dissolved ions in solution, which makes it difficult for the plant roots to take up water. In severe cases of high EC, roots may lose water under such conditions, leading to root damage or death. This generally occurs when there is insufficient leaching, plants are overfertilized or the irrigation water is of poor quality (high EC). Foliage may be dark-green and small, and plants may wilt even though the media is not dry.

A low EC means there are few dissolved ions in solution and it is easier for roots to take up water. The plants will be more lush and may be underfertilized since there are not as many nutrients available. However, root growth will be encouraged. Low EC often leads to a deficiency of one of the macro-elements (nitrogen, phosphorus, potassium, calcium, magnesium or sulphur).

How to Measure EC of the Growing Medium

There are four main ways to determine EC in a substrate sample:

- saturated-media extraction (SME) method
- Spurway (1 soil:2 water) dilution technique
- pour-through
- squeeze method

The SME and Spurway techniques involve removing a sample of substrate from the root zone and taking measurements of the filtrate. With the SME, sufficient water is added to the substrate, so that it becomes saturated, while with the Spurway technique, 1 volume of soil is mixed with 2 volumes of water. These are the most commonly used techniques in an analytical laboratory. Across North America, the SME is the most common greenhouse media extraction procedure used by university and private laboratories. The EC using SME is usually about 2.5 times greater than that measured by the 1:2 Spurway technique.

The pour-through technique is done by pouring distilled or deionized water at the top of the pot and collecting the first 50 mL of the leachate for EC and pH readings. This method is rapid and very useful for in-house monitoring, but the water has to be poured evenly and consistently over the soil surface. Another drawback is that high values can be found in some older (especially sub-irrigated) pots due to high salts at the top of the growing medium, while the root zone may actually have lower EC values.

Another option for in-house monitoring is the squeeze technique where plants are removed from the pot and the lower half of the root ball is squeezed to extract the root-zone nutrient solution. This gives a fairly good representation of the actual level *in situ* soil solution in contact with active roots. This technique is widely used for monitoring media EC in plug seedling trays. Because of the small sample solution extracted, a special EC meter, which uses only 1–2 drops of solution, must be used.

Interpretation of EC Data

The nutrient demand of a crop depends on the crop development and can be divided into three stages. Initially there is a low demand during seed germination or rooting of cuttings, followed by a high demand during the very active vegetative stage of crop growth and finally a lower demand as the plants reach maturity. As a general rule, shelf life is improved by lowering the nutrient levels (and reactivating the root system) towards the end of the crop (e.g., chrysanthemum and poinsettia); however, some crops such as Easter lily benefit from continued fertilization right up until shipping.

Table 2–2. *Relative EC Requirements of Actively Growing Greenhouse Crops Using the SME and Pour-through Methods*, provides suggested EC levels for the actively growing stages of various potted crops using two sampling techniques. For the initial and final growth stages, lower the EC by about 1.0 mS/cm. Sample five pots per representative area per week, and average and record the results.

If the EC is too low, add fertilizer to raise it.

If the EC is too high, leach with fresh water to lower it. Leaching can also be used for sub-irrigated crops although it is important to determine if the high salts are just in the upper part of the growing medium (which is normal in sub-irrigated crops and doesn't affect the root zone) or are in the root zone. If the root zone has a high EC, sub-irrigating with clear water is appropriate, as the salts are forced upwards.

Crops grown during low light conditions in the autumn and winter require a higher EC than during the summer, because reduced transpiration during this time of the year results in less water (and fertilizer) being taken up. In summer, the high transpiration rate and increased water uptake is often compensated by lower EC values in the nutrient solution.

TABLE 2–2. Relative EC Requirements of Actively Growing Greenhouse Crops Using the Saturated Media Extraction (SME) and Pour-through Methods

Nutrient Requirements	SME (mS/ cm)	Pour-through (mS/cm)	Crops
Low	0.75–2.0	1.0–2.6	African violet, azalea, begonia, calceolaria, calla, cineraria, cyclamen, geranium, gerbera, gloxinia, impatiens, orchid, primula, streptocarpus
Medium	1.5–3.0	2.0–3.5	Schlumbergera, clerodendrum, dahlia, exacum, zonal geranium, hibiscus, kalanchoe, lily, rose
High	2.0–3.5	2.6–4.6	Chrysanthemum, poinsettia

pH and Its Role

pH is an inverse measure (or a negative logarithm) of the concentration of hydrogen ions (H^+) in solution. A high number of H^+ ions results in a low pH and a low number of H^+ gives a high pH. pH is measured on a scale of 1–14 where a pH less than (<) 7.0 is acidic, more than (>) 7.0 is basic and 7.0 is considered neutral. The higher or lower the pH, the more strongly basic or acidic the solution. Each unit in the pH scale represents a change in the concentration of H^+ by a factor of 10.

Alkalinity

Alkalinity is a measure of the capacity of a product or solution to neutralize hydrogen ions. Alkaline products used in greenhouse production include dolomitic and calcitic limestone, hydrated lime, various fertilizers and substrates such as clay and sand. Alkalinity is somewhat connected to pH because it establishes the buffering capacity of a material; e.g., in solution with water it defines how resistant the water is to a change in pH. In Ontario, it is not unusual to have water with more than 200 ppm of bicarbonates, which originates from an underlying limestone base. In this case, the high concentration of bicarbonates neutralizes the hydrogen ions, resulting in a low concentration of H^+, and therefore a high pH. It should be noted that although there is a general correlation between pH and bicarbonate, this relationship is not specific. In other words, when you want to know how much acid to use to neutralize the pH, one has to know the amount of bicarbonates.

How to Measure pH

There are three main methods of measuring pH in solution:

- Litmus paper, which is the cheapest (but also the least accurate method), involves dipping the paper into the solution and comparing the colour change in the paper to established colour codes for different pH ranges.

- pH pens are reasonably priced, quite accurate and easy to carry around in the greenhouse. They are simply dipped into the solution to provide a digital readout of the pH.

- Electrode-type pH meters are the most accurate for measuring pH, but they are also the most expensive and require the most maintenance. Placing the pH probe directly into the solution until the reading stabilizes gives a quick reading. Many of the better pH meters have temperature compensation, but the temperature dependence is small (usually within 0.1–0.3 units). Rinse the probe between samples. Calibration is very important. The probes are not as stable as the probes of EC meters. Calibrate probes at least weekly using standard pH solutions of 4.0 and 7.0. Keep probes clean and stored in solution and replace more frequently than EC probes.

Check the pH of the substrate using the slurry or solution collected for measuring EC. In this case, use distilled water as many water sources have pH buffering compounds (e.g., bicarbonates) that can affect the pH.

Why Measure pH?

Although hydrogen ions are not considered one of the nutrient elements, pH does influence the solubility and thus the availability of other nutrients (especially micronutrients). For instance, most positive ions (cations) such as iron, manganese and calcium as well as phosphates, are more soluble at lower pH (and can be tied up in unavailable forms at higher pHs), while molybdenum is more available at a higher pH. The pH also directly influences the colonization of certain pathogens in the soil that maybe harmful to plants.

Different crops have different sensitivities to pH based on their sensitivities to some of these micronutrients (or lack of them). For example, pH <5.5 can result in the accumulation and toxicity of nutrients such as manganese and iron in marigold and geranium. In other plants such as azalea and hydrangea, a low pH is required to ensure maximum uptake of iron and aluminum essential for proper leaf and bloom colour. A pH of 5.5–6.5 is considered optimal for most crops grown in soilless mixes with more than 50% organic matter. Table 2–3. *Optimal pH Range for Various Crops*, lists crops with more specific optimal pH ranges.

TABLE 2–3. Optimal pH Range for Various Crops

Crop	Optimal Range
Marigold, geranium, celosia, Easter lily	6.0–6.6 (+/- 0.2)
Pansy, petunia, snapdragon, vinca, salvia, blue hydrangea	5.4–5.8
Azalea	4.8–5.4

Other factors to consider include the following:

- It is desirable for crops sensitive to low pH, such as geranium and marigold, to have slightly higher pH.

- Crops such as pot chrysanthemum, which tend to force the pH up over time, should have a lower pH early in the crop.

- Consider the stage of crop growth (age). At flowering, pH is often not as critical as it is earlier in the crop.

- The fertilizers being used also affect the pH of both the nutrient solution and media. Know whether the complete fertilizer you are using is basic or acidic in reaction. This is stated on the fertilizer packaging as the potential acidity by the number of kg of calcitic limestone per tonne of fertilizer. Likewise, if the fertilizer is basic in reaction, then it is stated as the potential basicity.

Because of the bicarbonate content and the use of soilless media, most growers now adjust the pH of their irrigation water using either phosphoric, nitric or sulphuric acid.

Adjusting the pH

Irrigation Water

For many smaller growers, injecting acid through their fertilizer injector is the method of choice. Be sure that the injector is designed to handle acids. For other growers, installation of in-line pH probes controlling an acid pump is the method of choice. Both methods work well. Rates of acid required are shown in Table 2–4. *Volume of Acid Required to Neutralize 61 ppm* HCO_3^- *per 100,000 L of Water.*

It is recommended to leave about 60 ppm bicarbonates in the irrigation water as a buffer and to provide a margin of error against small mistakes in calculation or dosing. Therefore, if the initial level of bicarbonates is 240 ppm, approximately 180 ppm needs to be neutralized; in this case, three times as much acid as is indicated in the table would be needed.

When 1 mmol/L of bicarbonate is neutralized with different acids, the following nutrients are added to the solution:

- if using nitric acid, 14 ppm nitrogen (in nitrate form)
- if using phosphoric acid, 31 ppm of phosphorus (as 71 ppm P_2O_5)
- if using sulphuric acid, 16 ppm sulphur (as 48 ppm sulphates)

TABLE 2-4. Volume of Acid Required to Neutralize 61 ppm HCO_3^- (1 mmol/L) per 100,000 L of Water

Acid	Spec. Gravity (kg/ L)	Volume of Acid (L)
Phosphoric (85%)	1.7	6.8
Nitric (67%)	1.5	6.6
Sulphuric (93%)	1.8	2.8

Media

If the pH is too low, consider one or more of the following steps:

For soilless mixes:

- Discontinue acidifying water supply.

- Shift to a basic-reaction fertilizer (high in nitrate nitrogen).

- Use potassium bicarbonate (100–200 kg/1,000 L) of stock @1:100 dilution, with an EC in the final solution of about 1.5–2.0 mS/cm.

- If limestone is used, the amount to be added depends on the type and ratio of the ingredients. Sphagnum peat moss (pH 3.5–4.5) and bark (pH 4.0) are acidic. The amount of limestone needed to neutralize sphagnum moss from a pH 3.5 to a pH 5.5 is about 6–7 kg/m^3 of loose peat moss. Alkaline materials are often the baked-clay types such as Haydite and Crackpot or sand. Adding clay additives with a high pH should reduce the amount of limestone needed. Check the pH after preparation but before planting. The pH of newly prepared moist media will continue to rise for about 10 days.

For soil beds:

- To increase the pH by 1 unit, use 4.8 kg limestone per 100 m^2.

- For a soil with a higher clay content or a higher organic matter content, increase the recommended amount by about 25%.

- Two to three weeks after application, check the soil pH to see if the desired pH level has been attained. Note that the finer the limestone, the quicker its reaction with the soil.

- The rate of pH change is also affected by temperature, moisture and aeration conditions of the soil. Changes will occur most rapidly when soils or soilless media are warm, moist and well-aerated.

- The use of hydrated lime in greenhouses has some severe drawbacks as it reacts very quickly and completely. Proper distribution of the material throughout the soil mixture is difficult and, consequently, the use of this material is very limited. However, it is used as a portion of the total limestone demand for soilless media in order to get a quick change in the pH, so that the media can be used for planting.

If the media pH is too high, it can be difficult to lower but one or more of the following steps will help:

- Increase the acidity of the irrigation water. Usually there is no harm in lowering pH of the nutrient solution to 5.2–5.4, while maintaining 30–60 ppm of bicarbonate (see above).

- Discontinue using basic-reacting fertilizers such as calcium nitrate.

- Instead use more ammonium-based fertilizers.

- Drench with iron sulphate @ 5 kg/1,000 L of water. Be sure to lightly wash the foliage immediately after to avoid burning.

- Use elemental sulphur @ 15 kg /1,000 L of water. This treatment requires 3–4 weeks to react.

See also Table 2–5. *Adjusting pH for Soilbeds.*

TABLE 2–5. Adjusting pH for Soilbeds

Materials	kg/100 m² to Lower pH 0.5–1 Unit*	Rate of pH Change
Finely ground sulphur	2.5	Slow
Aluminum sulphate	15	Rapid
Iron sulphate	15	Moderate

* Rates are for light to medium soils. For heavier soils with more organic matter, increase rate by one-third. The rates per m^3 of potting soils are one-half of the above recommended rates.

Soilless Growing Media

Soilless mixes have replaced soil-based mixes over the past 10–20 years. Whether the mix is used for plant growing, propagation, container growing, bench crops or even cut flowers, there has been a gradual reduction in the use of actual soil and an increase in the use of artificial ingredients. Soilless mixes are available already prepared in bags or bales, in bulk or as separate ingredients that can be blended together.

Why Use Soilless Mixes?

Soilless mixes offer several advantages over a conventional soil mix:

- There is uniformity and consistency from one batch to the next.
- Most are considered to be essentiallly disease and insect-free, thereby reducing the need for costly pasteurization.
- There is less likelihood of contamination from herbicide residues, which can occur with mixes containing field soil.
- The ingredients of a soilless mix are readily available and most are much lighter than soil.
- Soilless mixes have greater pore space and higher water-holding capacity than soil mixes.

Functions of a Good Growing Medium

A growing medium should perform four basic functions:

- provide an anchor system for the plant roots
- store water for plant-root absorption
- provide a buffer for nutrients absorbed by the roots
- provide oxygen (air space) for root respiration

Common Ingredients

Sphagnum peat moss

This is one of the most widely used materials, due to its physical characteristics and price. Sphagnum moss is a primitive plant that grows in bogs. While the upper part of the plant continues to grow, the bottom part dies, decomposing into peat. The moss leaves consist of living cells that may or may not contain chlorophyll, as well as dead "sphagnum" cells, which contain water and air. The dead sphagnum cells are unique in that they can absorb and conduct water. These cells have lignified walls that prevent their collapse when drying out. Water in these cells is absorbed by capillary action. Because the leaf and stem cells are surface active and are generally negatively charged, they can adsorb nutrients (e.g., positive ions) in a similar way to clay particles. Nutrients can also be absorbed in the sphagnum cells as dissolved ions in water.

A sphagnum peat bog has a top, middle and bottom. Because of the way sphagnum grows, the older mosses will be at the bottom and are the most decomposed. These are darkest in colour and finest in particle size. The top layers are more yellowish and coarser in structure. The coarser the peat, the lower the bulk density, the greater the air space and the lower the water-holding capacity (by volume).

The method of peat moss harvesting plays an important role in particle size distribution. Peat is harvested in two ways—the vacuum method and the block procedure. Vacuum harvesting involves loosening the surface, air drying and vacuuming the top surface of the bog. Block harvesting involves digging the peat in chunks and letting them dry over winter. The following spring, the chunks are loosened and packaged. Block-harvested peat is coarser than vacuum-harvested.

Cation exchange capacity (CEC) gives an indication of how many cations can be adsorbed per unit weight and how their supply to plants will be regulated (buffered). With its high CEC, peat moss is well suited as a nutrient reserve and buffering agent. Pure peat moss, however, contains very few nutrients as determined by the electrical conductivity of the saturated medium (EC< 0.5 mS/cm).

Due to its naturally low pH (3.5–4.5), peat moss is considered to be free of active pathogenic diseases, although dormant pathogenic spores or weed seeds may be present. Some people claim peat moss suppresses fungal diseases.

The low cost on a volume basis makes peat moss one of the more desirable mix ingredients. Normally, commercial and grower-made mixes today consist of 50%–100% sphagnum peat moss. The sphagnum peat mosses available in Ontario are generally sold in a compressed form and will expand by 40%–60% depending on compression level.

Vermiculite

This is a mica-like material that has been expanded under high temperature (900°C). This material can be compared to clay particles except that it has lost its swelling and shrinkage capabilities. It has a high cation exchange capacity (CEC), similar to peat moss on a weight basis and contains considerable potassium and magnesium ions. It improves air porosity, provides structure to the medium (less shrinkage) and makes rewetting of a mix easier. Water can also be absorbed internally between the platelets. Acidity is near neutral and bulk density is 80–100 kg/m^3. Three grades are normally available — coarse, fine and regular. It is mined in Washington and South Africa.

Perlite

This is an aluminum-silicate of volcanic origin that has been heated to about 1,000°C. It is similar to popcorn as it consists of a number of closed, air-filled cells. Water is absorbed primarily on the outer surface and to a lesser degree within the particle. This inert material is primarily added to the mix to improve aeration and drainage as well as structural stability. The pH is about 7.0 and the CEC is negligible. Bulk density is similar to that of vermiculite or peat moss, about 100 kg/m^3.

Coir

Coir is the coarse fibre pith produced as a byproduct when the long lignin fibres are extracted from the fibrous outer husk of the coconut fruit. These fibres are typically washed with fresh water to remove the excess sodium and chloride ions prior to processing for horticultural uses. It has a high water holding capacity, 8–9 times its dry weight. It has excellent wetting properties and high cation exchange capacity. The pH is typically 5.7–6.5. EC sampling of each shipment should be done by growers prior to planting to ensure that the coir was adequately washed. Coir is available as 1 L compressed bricks that will expand to 8-9 L of fluffed up material, as chunks and as compressed 1 metre slabs sleeved with plastic for greenhouse vegetable production. Compressed bricks that fail to expand properly when wetted should be discarded. Currently coir is being used for production of long-term cut flower crops such as gerbera and roses grown in containers or troughs.

Rockwool

This product is manufactured from basalt and limestone by spinning the molten rock. There are two forms available, namely, the bonded product and the granulated material. The base material is sterile and does not contain any CEC or an appreciable level of soluble salts. The bonded product is cut into slabs 15 or 20 cm wide, 7.5–10 cm thick, and 90–200 cm long and is used primarily for the production of greenhouse vegetables (tomato, cucumber and pepper) or cut flowers (rose, gerbera). It can be purchased with or without a plastic sleeve. Slabs contain a binder for stability and a wetting agent to facilitate water absorption and distribution. The granulated material comes in three sizes (fine, medium and coarse) and does not contain any binder and/or wetting agent. Granulated rockwool is added to a mix to increase pore space and water-holding capacity and for easier rewetting if the medium is allowed to dry out. Rockwool is currently used for the production of a few long-term cut flower crops such as roses and gerbera and greenhouse vegetable crops.

Rockwool can also be manufactured from steel slag. This material, often referred to as mineral wool, generally has a relatively high pH (7–8) and higher levels of micronutrients compared to rockwool.

Polystyrene chips

This is a waste product created from polystyrene bead boards. The material is inert, with negligible CEC and near-neutral pH. Its role in a media is similar to perlite except that there is no surface absorption of water. Bulk density is 25 kg/m^3 and it cannot be pasteurized due to shrinkage. It has a tendency to float to the surface of the pot and can be a nuisance with recirculating sub-irrigation systems. Soil-mix uniformity can be of concern because of its tendency to separate from the rest of the mixture.

Turface®

This is a baked clay with neutral reaction (pH 7.0). Because the bulk density is 750 kg/m^3 and the CEC is high for regular grade, the material is used to increase the weight and the buffering capabilities of the mix. The CEC is about the same as vermiculite.

Haydite®

This is a shale expanded by treating to 1,200°C. Bulk density is about 800 kg/m^3 depending on size and grade. It has a high pH (8.5–9.5) and can be obtained in several grades according to particle size. The neutralizing capacity of this material has to be considered when used in appreciable quantities.

Gro-Bark®

Composted barks may suppress toxic substances and plant pathogens. Hardwood barks are generally composted for three months, while softwood barks take about 1½ months to compost. Nitrogen is generally added at 1 kg or 0.5 kg/m^3 for hardwood and softwood bark, respectively, before composting. Gro-Bark, a commercially available product, is a blend of aged pine bark and sawdust that has been naturally composted for 10–40 years. It ranges in pH from 4.5–6.5 and is low in salts. Available in bulk only, it is often used as bedding in walkways, as an amendment for containerized nursery material or as a substitute for peat moss.

Grow-Rich®

Grow-Rich is a composted material produced from papermill sludge and other organic materials (animal manures, sawdust and corncobs). The bulk density is about 400 kg/m^3, while typical particle size ranges from 3–6 mm. The pH is between 5.5 and 6.5, and soluble salts are near 1.5–2.0 mS/cm, using the saturated-medium extraction method. As a consequence, the final potting mix should not contain more than 25% of this material.

Worm Castings

Worm castings are a byproduct of worm raising. They are high in organic content and stable in structure. The pH is 6.0–7.5 while soluble salts are between 1.0 and 1.5 mS/cm. Bulk density is about 200 kg/m^3. It should be used sparingly in a mix (less than 25% of the volume) to provide structural stability and more pore space to the media. It is somewhat hydrophobic in nature, may contain weed seeds and is quite expensive.

Sand

Although technically a type of soil, sand is quite often incorporated into soilless mixes to provide weight. It is about 15 times heavier than the other major components (peat, perlite and vermiculite). Drawbacks with sand include:

- its grinding action on the other ingredients if mixed too long, which causes a reduction in air space
- its potential for containing plant pathogens, therefore requiring pasteurization

However, sand (similar to soil) improves wettability of the mix. Depending on its source in Ontario, sand often has a high pH (about 8.5), which indicates the presence of free calcium carbonates. When you use, consider its neutralizing capacity.

Physical Characteristics of a Soilless Mix

A soilless (or soil) mix has three major components — air, solids and water. The air space is needed to provide oxygen for root respiration and to allow nitrification and some microbial activity. The air space in a mix complements the water portion, since air replaces the water absorbed by the plant roots. The air/water ratio in a mix is determined by the particle size of the solids. After a coarse mix is watered, air will enter the mix more quickly than in finer mixes but may not be distributed uniformly. Therefore, a coarse mix has relatively more air and less water-filled pore space than a fine one. A lack of air space can be a problem when using a fine-textured mix during the lower light periods of the year. Another factor that affects the air:water ratio is the height of the pot; the taller the pot, the greater the air:water ratio, especially in the top of the pot.

After watering, a soilless mix may have up to 75% of the total space filled by water, with the remainder taken up by solids (5%–10%) and air (15%–20%). In a soil mix, solids compose 50% of the space, with the balance divided between air and water. This basic difference between a soil and a soilless mix therefore necessitates a change in crop management. The bulk density of most soilless mixes is about 100–200 kg/m^3. Shrinkage of the mix is of some concern due to the changing physical properties, but also due to the volume of the medium required for a given pot size. Peat moss and rockwool will both shrink. The addition of structural components such as perlite or vermiculite or compressing the mix when filling the pots, helps to alleviate medium shrinkage.

See also Table 2–6. *Example of a Soilless Mix with Amendments.*

Preparing a Soilless Mix

There are several considerations to take into account when preparing a soilless mix:

- water-holding capacity
- air porosity
- nutrient availability
- buffering capacity
- weight
- price

TABLE 2–6. Example of a Soilless Mix with Amendments

Ingredients	Percent (by volume)
Sphagnum peat moss	50–60%
Vermiculite, perlite, polystyrene, bark, granulated rockwool	20–40%
Turface®, Haydite®, sand	10–20%
Amendments	Rate/m^3 of mix
Limestone (fine grade, dolomitic)	3.5 kg
Superphosphate	1.5 kg
Potassium nitrate (12-0-44) or ammonium nitrate (34-0-0)	1.0/0.4 kg
Trace elements	0.25–0.5 kg
Wetting agent	100 mL

The major component in most soilless mixes is sphagnum peat moss due to its excellent growing properties. The quality of the peat moss is important as it is the principal ingredient. A coarse peat provides more natural air space and could be used at a higher percentage in the mix. A finer mix, with less air space, should constitute less of the final mix. For aeration purposes and to give structure to the mix (with less shrinkage), use one or a combination of the following ingredients: vermiculite, perlite, granulated rockwool or polystyrene chips. Vermiculite and rockwool are excellent materials, as they increase water-holding capacity and have good rewetting characteristics. The third ingredient (Turface®, Haydite® or sand) is added for weight, buffering capacity and/or pore space.

Add limestone (3.5 kg/m^3 of mix) to bring the pH of the mixture to an acceptable level (based on a mix containing 50% peat moss). The amount of limestone indicated does not take into account any neutralizing effects from the other ingredients (e.g., Haydite®, sand) or the acidifying effect of some fertilizers (ammonium nitrate). It may take one week after mix preparation and initial wetting before the pH is stabilized.

When using calcitic limestone, supply magnesium in the form of Epsom salts (0.5 kg/m^3). Add superphosphate for phosphorus, sulphur and calcium. If nitrogen and/or potassium are also added, use potassium nitrate (12-0-44) at 0.5–1.0 kg/m^3, or ammonium nitrate (34-0-0) at 0.3–0.5 kg/m^3. The nitrogen addition would amount to about 0.25–0.50 g nitrogen per 15-cm pot. In some instances, calcium nitrate may be used as the nitrogen source at 0.5 kg/m^3. Use Nutritrace or a similar micro-element mix to add trace elements Fe, Cu, B, Zn and Mn. As a wetting agent, a non-ionic reagent such as Aqua-Grow® or Agral-90 is suitable. Dissolve the wetting agent in warm water and spray over the mix for uniform distribution. Sometimes a combination of trace elements and wetting agent is available in granular form. For convenience purposes, many growers have their amendments premixed by their fertilizer supplier. Most ingredients can be mixed when dry. Screw-turn and tumbler-type mechanical mixers can be used, but prevent pulverization of components by minimizing mixing time. Add water when the ingredients are being mixed to prevent dust and promote stable particles.

Chemical Characteristics of Mixes

After preparing a mix, always check the total soluble salts (EC) and pH. The EC gives an indication of the nutrient status by measuring the conductivity of the solution, while the pH plays a major role in determining the nutrient availability (see EC section on page 16). The optimal pH for organic soilless mixes is around 5.5 (±0.5). This contrasts with the recommendation of pH 6.5 for soil mixes. In the peat-like mixes, a high pH (over 6.5) can cause iron (Fe), manganese (Mn), boron (B), copper (Cu), zinc (Zn) and phosphorus (P) deficiencies, while a pH of 5.0–5.5 can cause molybdenum deficiency (especially in poinsettia). Adding ammonium nitrate (34-0-0) at 400 g/m^3 may reduce the pH by about 0.5.

Ready-Made Mixes

Most commercially prepared mixes have been tested and will perform well when managed properly. When you compare prices between commercial mixes and mixing your own, consider the costs of materials, mixing, equipment, storage space and labour. Smaller operations often use ready-made mixes. Some manufacturers will blend and deliver mixes to growers' specifications. The ready-made mixes usually follow the above outline of ingredients, although the third major ingredient (Turface® or sand) is usually omitted. Most ready-made mixes have a pH of 5.5–6.0 and an EC of 1.2–1.8 mS/cm using the saturated-media extraction method, while the water-holding capacity is about 70% on a volume basis after a 15-cm pot is totally saturated and allowed to drain.

Composts

Some growers may choose to use composted material as part of their soilless mix. Composts may contain antagonistic fungi and bacteria (to suppress plant diseases) as well as other beneficial microorganisms (such as nitrifying bacteria). Composts made from assortments of organic byproducts are available in bulk from various suppliers at relatively low costs. These may be used successfully as amendments but it is advisable to check pH and soluble salts before use.

Common Problems with Soilless Mixes

Mixing the ingredients of a soilless mix for too long grinds the particles together, breaking them down and thereby destroying medium structure. A general guideline is 3–5 minutes at 12–14 rpm.

Rewetting a soilless mix after it has dried out is difficult, but not impossible. Use several light waterings or mist applications. Alternatively, add a wetting agent to the water at approximately 1 mL/L of warm water. Normally the wetting agent is added when mixing the ingredients. Adding granulated rockwool or vermiculite improves the rate of rewetting after severe drying out. Excessive levels of wetting agent incorporated into the medium (e.g., 2–3 times the recommended rate) can result in the development of only a few long stringy roots or a failure of the roots to penetrate the medium. This may cause overall stunting of sensitive species, including impatiens, begonia and cucumber.

Algal growth on the surface may restrict seedling emergence, reduce water penetration and/or serve as a food source for fungus gnats. Some fungicides may reduce algal growth. As the plants grow, reduced light levels on the surface also will restrict development of algae. Agribrom added to the irrigation water at 5–10 ppm of residual bromine will help to control/prevent algal growth. Algae-free irrigation water also reduces this problem.

Optimal nutrient levels are usually higher than in a soil mix. Therefore, keep the crop well fertilized. Soluble salts readings can safely be about twice as high as those in a soil mix.

Symptoms of magnesium deficiency show up quickly on crops such as tomato and chrysanthemum. This is because most conventional water-soluble "complete" fertilizers do not contain magnesium. Preplant incorporation or separate feedings of Epsom salts (magnesium sulphate) or magnesium nitrate will help prevent this situation.

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The Role of Nutrients in Plant Growth

Plant nutrients can be divided (depending on the quantity required of each by the plant) into macro and micronutrients. See Table 2–7. *Macro- and Micronutrients in Plants*. Also shown is the form in which the element is taken up by the plant and its mobility within the plant.

TABLE 2–7. Macro- and Micronutrients in Plants

Elements	Form	Mobility
Macronutrients		
Carbon (C)	Carbon dioxide (CO_2)	M
Hydrogen (H)	Water (H_2O)	M
Oxygen (O)	CO_2, H_2O	M
Nitrogen (N)	Ammonium (NH_4^+), Nitrate (NO_3^-)	M
Phosphorus (P)	Dihydrogen phosphate ($H_2PO_4^-$)	M
Potassium (K)	Potassium (K^+)	M
Calcium (Ca)	Calcium (Ca^{2+})	I
Magnesium (Mg)	Magnesium (Mg^{2+})	M
Sulphur (S)	Sulphate (SO_4^{2-}), Sulphur dioxide (SO_2)	M
Sodium (Na)	Sodium (Na^+)	N/A
Silicon (Si)	H_4SiO_4	N/A
Micronutrients		
Iron (Fe)	Ferrous (Fe^{2+}), Ferric (Fe^{3+})	I
Manganese (Mn)	Manganese (Mn^{2+})	I
Copper (Cu)	Copper (Cu^{2+})	I
Zinc (Zn)	Zinc (Zn^{2+})	I
Molybdenum (Mo)	Molybdate (MoO_4^{2-})	M
Boron (B)	Boric acid (H_3BO_3)	I
Chlorine (Cl)	Chloride (Cl^-)	M
Aluminum (Al)	Aluminum (Al^{3+})	M

M = mobile, I = immobile, N/A = not available

There are two main factors affecting the mineral content of a plant. The first is genetically determined and accounts for the fact that N and K content of many plants (46%) is about 10 times higher than that of P and Mg, which are in turn 100–1,000× higher than most micronutrients.

The second is the availability of nutrients in the growing medium and the ability of the plant to absorb them. In practice, this is the only factor growers can influence. Up to a certain level, the nutrient content of a given plant increases with a higher content of nutrients in the growing medium. Beyond this optimum level, no benefit can be expected from further increase in availability.

Uptake and Translocation of Nutrients

Macronutrients

In general, all macronutrients except calcium are mobile within the plant. Mobile nutrients can move in both the xylem and phloem and will be translocated to where they are most needed, usually developing shoots, flowers or bracts.

- **Carbon** — is taken up primarily in the form of CO_2 through the stomata in the leaves. It is then transformed into organic material through the process of photosynthesis. To a lesser extent it may also be taken up in the bicarbonate form (HCO_3^-) from the nutrient solution.

- **Hydrogen** — water is the major supplier of H^+ through absorption by the root hairs.

- **Oxygen** — is taken up as CO_2 during daylight and as oxygen dissolved in water through the roots.

- **Nitrogen** — both ammonium (NH_4^+) and nitrate (NO_3^-) forms can be absorbed by the roots and metabolized by the plants. The rate of NO_3^- uptake is usually greater than that of NH_4^+. However, this depends strongly on pH. NH_4^+ uptake occurs best in a neutral medium and decreases with a lower pH. The reverse is true for NO_3^-. High carbohydrate levels in the plant (e.g., during summer) favour uptake of NH_4^+. Within the xylem, nitrogen is transported as nitrate and amino acids.

- **Phosphorus** — the majority of P is actively taken up (from very low concentrations in the soil to higher levels in the xylem) as $H_2PO_4^-$.

- **Potassium** — is taken up as K^+, often actively and is mobile within the plant.

- **Calcium** — is absorbed passively (from higher concentrations in the soil to lower concentrations in the plant) as Ca^{2+}. Calcium in the xylem sap is translocated in an upward direction within the transpiration stream and thus depends on transpiration rate and humidity (or vapour pressure deficit). Uptake is also favoured by NO_3^-. Within the plant, calcium is not mobile.

- **Magnesium** — the competitive effects of other cations (e.g., potassium and ammonium) are important in determining rate of magnesium uptake. It is taken up passively by the transpiration stream and is mobile in the xylem.

- **Sulphur** — plants absorb sulphur mainly in the form of sulphate (SO_4^{2-}), which may be taken up actively.

Micronutrients

All micronutrients are essentially immobile. They can be absorbed by the roots, moved through the plant in the transpiration stream and distributed to various plant parts. However, they cannot be moved out of the various plant tissues and redistributed to other plant parts if needed.

- **Iron** — uptake is influenced by rate of plant metabolism as well as by the presence of other cations such as manganese (Mn^{2+}) and copper (Cu^{2+}). Iron uptake is depressed by high pH, root damage and high levels of phosphate, manganese, boron and calcium; it is enhanced by high ammonium (NH_4^+). Iron (Fe^3+) is not mobile between plant parts.

- **Manganese** — uptake is influenced by plant metabolism (similar to iron). Low soil temperature causes low metabolic activity and therefore reduced uptake (e.g., roses in soil beds in winter). Manganese is relatively immobile in the plant. Young plant tissue is usually rich in Mn^{2+}. Manganese availability is enhanced by low pH.

- **Copper** — similar to iron and manganese. Copper (Cu^{2+}) is not very mobile within the plant but can be translocated from older to younger leaves. There are generally very low levels in the plant compared to other micronutrients.

- **Zinc** — there is some disagreement as to whether zinc (Zn^{2+}) uptake is passive or active, although most researchers consider it active. It has a strong interaction with copper. Zinc is not very mobile within plants.

- **Molybdenum** — there is not a great deal known about molybdenum (MoO_4^{2-}) except that poinsettia is one of a few plant species known to be sensitive to low levels. Molybdenum is important in the function of a major enzyme in plant metabolism.

- **Boron** — is probably taken up as undisassociated boric acid (H_3BO_3) and follows water flow through the roots. It is immobile within the plant and is concentrated more in older rather than younger leaves. Deficiency is found in the plant tip and toxicity in the older leaves.

Nutrient Analysis

Testing of water, growing media and tissue for nutrient analysis can be done through accredited tesing laboratories in Ontario, see *Appendix C* on page 146.

Water

The raw water used for irrigation purposes should contain all the major elements needed for plant nutrition; however, the quantities must be adjusted based on a nutrient analysis. Water analysis will also indicate whether the water source is contaminated (not by microbial contamination) or whether the concentration of specific ions such as fluoride (F^-) or boron (B) may be too high. In addition, the bicarbonate level has to be known (not necessarily the pH) so the required amount of acid can be calculated to obtain a given pH. Table 2–8. *Maximum Desirable Concentrations of Specific Ions in Raw Water Used for Irrigation Purposes in a Greenhouse Using Soilless Substrates (Rockwool, Oasis, Peat or Coir)*, lists the most common elements involved in plant nutrition and desirable levels in raw water to be used for irrigation.

TABLE 2–8. Maximum Desirable Concentrations of Specific Ions in Raw Water Used for Irrigation Purposes in a Greenhouse Using Soilless Substrates (Rockwool, Oasis, Peat or Coir)

Element	Maximum Desirable (ppm)
Nitrogen (NO_3^-)	5
Phosphorus ($H_2PO_4^-$)	5
Potassium (K^+)	5
Calcium (Ca^{2+})	120
Magnesium (Mg^{2+})	25
Chloride (Cl^-)	100
Sulphate (SO_4^{2-})	200
Bicarbonate (HCO_3^-)	30–60
Sodium (Na^+)	60
Iron (Fe^{3+} or Fe^{2+})	5
Boron (B)	0.5
Zinc (Zn^{2+})	0.5
Manganese (Mn^{2+})	1.0
Copper (Cu^{2+})	0.2
Aluminum (Al^{3+})	5
Molybdenum (Mo)	0.02
Fluoride (F^-)	1
pH (H^+)	5.0–7.0

Following are comments regarding the various elements:

- **N, P, K** — Although used for fertilization purposes, the presence of high levels of these elements (nitrogen, phosphorus and potassium) in the raw water indicates contamination.

- **Ca^{2+} and Mg^{2+}** — The maximum desirable levels described above provide adequate levels of nutrition for most crops. Higher values do not necessarily mean toxicity but can contribute to the hardness of the water.

- **HCO_3^-** — Most water sources in southern Ontario contain bicarbonates (HCO_3^-) in excess of the given range. Bicarbonates are not very toxic, but levels of 250+ ppm may create problems for plant growth. High levels provide a high alkalinity (pH), which over time may increase pH levels in the growing medium. The precipitation of calcium and/or magnesium carbonates causing leaf residues and the plugging of emitters is another disadvantage of high carbonate levels. Neutralize high bicarbonate levels by using nitric, phosphoric or sulphuric acid. See *Adjusting the pH* on page 19.

- **Fe^{3+}** — Iron in its oxidized form has a low solubility and can therefore easily precipitate as amorphous iron hydroxide, which plugs emitters. For drip-irrigation systems, levels higher than 0.25 ppm are undesirable.

- **B** — Boron can be quite toxic to plants and should be carefully controlled in substrate culture (less than 0.5 ppm) or for a recirculating system (less than 0.25 ppm).

- **Zn^{2+}** — Zinc can be found in water sources that have been in contact with galvanized metal (e.g., the rainwater from greenhouse roof using galvanized gutters). Again, the ions may accumulate in recirculating systems.

- **Mn^{2+}** — Although manganese is not often a problem except under special circumstances (steam pasteurization), it is believed to be toxic at high levels.

- **Cu^{2+}** — Copper levels may be higher than 0.2 ppm if organic media are used.

- **Al^{3+}, Mo, F^-** — Aluminum, molybdenum and fluoride are not commonly found at high concentrations in the water source. However, fluoride can cause serious damages to monocotyledons (lily, dracaena, spider plant). Cleaning compounds for greenhouse roofs (to remove white wash), which often contain fluoride, should not be allowed to drain into a cistern or pond.

- **pH** — Although hydrogen ions are not considered a nutrient element it is important to include this factor, as the availability of most nutrients is pH-dependent. For instance, most positively charged ions such as Fe, Mn and Ca, as well as phosphates, are more soluble (and therefore more available to the plant) at low pH, while molybdenum is more available at a higher pH. Most water sources in Ontario have a pH of about 7.5, due to high levels of bicarbonates. Acidification may be required. See *Adjusting the pH* on page 19. A pH lower than 5.0 is detrimental to the structure of rockwool slabs.

See *Appendix C* on page 146 for laboratories in Ontario that are accredited by OMAFRA to analyse water, nutrient solutions and media.

Soilless Media

Media testing for nutrient analysis used to be done by mixing water with the soil at a ratio of 1:2 (air-dried soil: water) and was called the Spurway test. Now the saturated-medium extract method using distilled water is the most widely used in North America; it measures the nutrients directly in the extract. This procedure provides an estimate of what is readily available to the plant in the root zone.

Sampling the Growing Medium

- **Soil** — Using a soil probe, take sufficient samples (20) of the area (ground beds) at a depth of between 10 cm and 25 cm and bulk the samples. Mix the bulked sample well, take a representative sample (approximately 600 g), put in a plastic bag and send to an OMAFRA-accredited laboratory approved for Saturated-Medium Extraction analysis. See *How to Measure EC of the Growing Medium* on page 17 and *Appendix C* on page 146. Analysis is done on a fee-for-service basis. For seasonal crops, have the soil tested well before the crop is planted. Allow enough time between sending the samples and planting the crop to make nutrient or pH adjustments.

- **Potting media** — Sample only the bottom two-thirds of the potting substrate (do not include the top layer, particularly when the crop is being sub-irrigated). Bulk together 20 samples; from this take a representative sample of approximately 600 g, place in a plastic bag and send to the laboratory. Growers should run their own EC and pH tests (between regular sampling for laboratory analysis) by drenching a number of pots with distilled water and measuring the leachate. These results compare fairly closely to the Saturated-Medium Extract used by a laboratory (see *Interpretation of EC Data* on page 18) and give a good indication of the total nutrient status, but not of the individual elements. To accurately track nutrient levels in the media, collect biweekly samples.

For interpretation of results and for adjustments to the growing medium, consult a greenhouse floriculture specialist.

Foliar

In floriculture, leaf tissue analysis is used primarily as a diagnostic tool to verify deficiency or toxicity symptoms, but also can be used to monitor nutrient levels during the cropping period. Different plant parts contain different levels of nutrients, but analysis of leaf tissue is most commonly used for diagnosing nutrient availability (uptake) in the soil. The mineral content of plants is usually expressed as a percentage on a dry weight basis for the macro-elements (N, P, K, etc.). For micro-elements (Fe, Mn, Cu, Zn, B, Mo), mineral content may be expressed as milligram per gram (mg/g) or parts per million (ppm) of plant dry matter. Age of the plant parts is important as well. Young plant tissue tends to have higher contents of N, P and K compared to older tissue, which generally has higher levels of Ca, Mn, Fe and B. Therefore, harvest the most recently matured leaves of a plant for tissue analysis, if testing regularly to monitor the nutrient status.

Foliar analysis is often a more accurate way to assess the micro-nutrient status of the crop or the fertility program than analyzing the media micro-nutrient levels. Sample the most recently matured leaves from several plants unless indicated otherwise. Usually 30–50 leaves are sufficient. Avoid leaves with disorders unless that is to be diagnosed, in which case take them as a separate sample. Ensure that samples are not contaminated with pesticides or foliar applications of fertilizer. If in doubt, rinse the leaves in distilled water and let them dry before packaging and sending them to the laboratory. Laboratories generally prefer paper bags over plastic so that the leaves do not rot in transport.

Table 2–9, *Tissue Analysis Guidelines*, provides an overview of the desirable ranges of nutrients. Factors that can affect nutrient content include plant age, position on plant (upper vs. lower leaves), cultivar, season, fertilizer regime, number of days after fertilization, media pH, growth regulator application, presence of disease and temperature. These values are a guide only.

TABLE 2–9. Tissue Analysis Guidelines

Nutrient	**African violet**	**Alstroemeria**	**Azalea**	**Rieger begonia**	**Wax begonia**	**Zygocactus (Schlumbergera)**	**Caladium**
Nitrogen (%)	2.2–2.7	3.8–7.6	2.2–2.8	3.4–4.6	4.4–5.2	2.7–3.7	3.6–4.9
Phosphorous (%)	0.2–0.9	0.3–0.7	0.2–0.5	0.4–0.8	0.3–0.4	0.5–0.9	0.4–0.7
Potassium (%)	1.5–6.0	3.7–4.8	0.7–1.6	2.0–3.5	3.4–4.2	6.2–7.1	2.3–4.1
Calcium (%)	0.6–1.7	0.6–1.4	0.2–1.6	0.7–2.4	1.3–2.1	0.7–0.9	1.1–1.6
Magnesium (%)	0.7–1.1	0.2–0.4	0.1–0.6	0.3–0.8	0.6–1.0	1.6–2.2	0.1–0.3
Iron (ppm)	70–320	175–275	50–150	80–390	100–260	105–110	65–90
Manganese (ppm)	35–490	60–90	30–300	35–190	90–355	35–130	110–135
Zinc (ppm)	20–80	35–70	5–60	20–30	50–65	50–65	125–135
Copper (ppm)	5–30	5–15	5–15	5–10	10–15	10–15	5–10
Boron (ppm)	30–200	10–50	15–100	35–130	30–40	65–70	95–145

Nutrient	**Calla**	**Carnation**	**Chrysanthemum**	**Cyclamen**	**Dieffenbachia**[1]	**Easter lily**	**Exacum**
Nitrogen (%)	2.9–3.0	3.0–5.0	4.0–6.0	2.9–5.0	3.0–4.0	2.4–4.0	3.8–5.3
Phosphorous (%)	0.3–0.4	0.1–0.5	0.2–1.2	0.4–1.0	0.7–1.0	0.1–0.7	0.3–0.7
Potassium (%)	3.9–4.4	2.0–6.0	1.0–10.0	1.2–4.5	6.4–8.2	2.0–5.0	2.3–3.4
Calcium (%)	0.9–1.1	0.6–2.0	0.5–4.6	0.3–1.3	1.9–2.4	0.2–4.0	0.5–0.8
Magnesium (%)	0.3–0.4	0.2–0.6	0.1–1.5	0.4–1.3	0.4–0.8	0.3–2.0	0.4–0.7
Iron (ppm)	95–130	30–150	20–750	150–550	50–300	100–250	55–155
Manganese (ppm)	635–690	30–445	25–375	100–500	50–300	50–250	70–165
Zinc (ppm)	30–45	15–75	5–35	30–100	40–200	30–70	25–85
Copper (ppm)	5–10	5–30	5–50	5–20	3.5–30	5–25	5–75
Boron (ppm)	30–40	20–400	20–200	70–350	10–30	20–50	25–60

Nutrient	**Ficus benjamina**[1]	**Freesia**	**Fuchsia**	**Ivy geranium**	**Regal geranium**	**Seed geranium**	**Zonal geranium**
Nitrogen (%)	2.0–2.5	2.7–5.6	2.8–4.6	3.4–4.4	3.0–3.2	3.7–4.8	3.8–4.4
Phosphorous (%)	0.2–0.4	0.4–1.2	0.4–0.6	0.4–0.7	0.3–0.6	0.3–0.6	0.3–0.5
Potassium (%)	2.1–2.5	3.1–5.9	2.2–2.5	2.8–4.7	1.1–3.1	3.3–3.9	2.6–3.5
Calcium (%)	1.7–2.5	0.4–1.0	1.6–2.4	0.9–1.4	1.2–2.6	1.2–2.1	1.4–2.0
Magnesium (%)	0.3–0.4	0.3–1.8	0.4–0.7	0.2–0.6	0.3–0.9	0.2–0.4	0.2–0.4
Iron (ppm)	50–200	80–115	95–335	115–270	120–225	120–340	110–580
Manganese (ppm)	25–100	30–540	75–220	40–175	115–475	110–285	270–325
Zinc (ppm)	20–75	40–110	30–45	10–45	35–50	35–60	50–55
Copper (ppm)	5–10	5–130	5–10	5–15	5–10	5–15	5–15
Boron (ppm)	20–40	30–100	25–35	30–280	15–45	35–60	40–50

TABLE 2–9. Tissue Analysis Guidelines (cont'd)

Nutrient	Gerbera	Gloxinia	Hibiscus	Hydrangea	Common impatiens	Nephrolepis[1]	New Guinea impatiens
Nitrogen (%)	3.3–4.1	3.3–3.8	3.5–4.5	2.0–3.8	4.3–5.3	1.7–2.5	3.3–4.9
Phosphorous (%)	0.3–0.7	0.3–0.5	0.2–0.6	0.3–2.5	0.6–0.8	0.3–0.6	0.3–0.8
Potassium (%)	3.1–3.9	4.5–5.0	2.0–2.9	2.5–6.3	1.8–2.8	2.5–3.9	1.9–2.7
Calcium (%)	0.9–4.2	1.5–2.2	1.9–2.3	0.8–1.5	2.9–3.3	0.9–1.3	1.9–2.7
Magnesium (%)	0.3–2.8	0.4–0.5	0.5–0.7	0.2–0.4	0.6–0.8	0.6–0.7	0.3–0.8
Iron (ppm)	80–130	70–150	60–75	85–115	405–685	30–300	160–890
Manganese (ppm)	65–260	95–170	135–180	100–345	205–490	49–181	140–245
Zinc (ppm)	30–80	20–35	35–50	50–105	65–70	52–149	40–85
Copper (ppm)	5–10	5–20	5–10	5–10	10–15	10–15	5–10
Boron (ppm)	25–50	30–35	20–25	35–50	45–95	20–40	50–60

Nutrient	Kalanchoe	Petunia	Poinsettia	Primula	Rose	Snap-dragon	Strepto-carpus[1]	Vinca
Nitrogen (%)	2.5–5.0	2.8–5.8	4.0–6.0	2.5–3.3	3.0–5.0	4.0–5.3	2.0–3.5	4.9–5.4
Phosphorous (%)	0.2–0.5	0.5–1.2	0.2–1.0	0.4–0.8	0.2–0.3	0.2–0.6	0.1–0.7	0.4–0.6
Potassium (%)	2.0–4.8	3.5–5.5	1.5–5.0	2.1–4.2	1.8–3.0	2.2–4.1	4.8–5.5	2.9–3.6
Calcium (%)	1.1–4.5	0.6–4.8	0.4–2.0	0.6–1.0	1.0–1.9	0.5–1.4	1.2–1.9	1.4–1.6
Magnesium (%)	0.4–1.0	0.3–1.4	0.2–1.0	0.2–0.4	0.2–0.4	0.5–1.0	0.3–0.5	0.4–0.5
Iron (ppm)	75–200	40–700	100–300	75–155	50–150	70–135	90–260	95–150
Manganese (ppm)	60–250	90–185	45–300	50–80	30–900	60–185	130–300	165–300
Zinc (ppm)	25–80	30–90	25–150	40–45	15–50	30–55	85–130	40–45
Copper (ppm)	5–20	5–45	5–15	5–10	5–25	5–15	15–20	5–10
Boron (ppm)	30–60	20–50	20–200	30–35	20–60	15–40	55–65	25–40

[1] Numbers from *Guide Values for Nutrient Element Contents of Vegetables and Flowers under Glass*, Glasshouse Crops Research Stations, Aalsmeer and Naaldwijk, 1987. (Assembled and updated by R.E. Widmer, University of Minnesota, June 1985. Expanded and updated by J.M. Dole and H.F. Wilkins, University of Minnesota, October 1988, Department of Horticultural Science and Landscape Architecture.)

Recommended portion of plant to sample:

- chrysanthemum—uppermost leaves from mature flowering shoots
- exacum—shoot tips with one pair of mature leaves and all immature leaves
- rose—uppermost five-leaflet leaf on flowering stems
- other crops—the most recently mature leaf

Symptoms of Nutrient Deficiency

(Source: *Diagnosing Nutrient Disorders in Greenhouse Crops*, C. Rosen and J. Erwin, University of Minnesota).

Nutritional Interactions

Nutritional problems in greenhouse crops can be common because of the high rate of growth, the different specific requirements of each crop, the limited rooting volume of the container and the limited nutrient reserve of the medium in which the crop is grown. Both the amount of nutrients being supplied and their balance play important roles in the production of high-quality crops. Changing the level of one nutrient in solution can affect the uptake or transport through the plant of another. Although interactions between nutrients can be either positive or negative, it is usually the negative interactions that are most well documented.

Nutrient interactions become a factor in two situations:

- when the levels of two elements are near the deficiency range, and
- when one element is supplied in excessive amounts while another is at levels that are marginally sufficient

The precise nature of the interaction depends on the nutrients involved and the plant species. It may be the result of precipitation reactions occurring in the soil solution or the result of competition during ion uptake, translocation or metabolic function. See Table 2–10, *Some Common Interactions Between Nutrients*. In many cases, the mechanism for the interaction may not be completely understood. These antagonistic effects become important when nutrient levels are low.

TABLE 2–10. Some Common Interactions Between Nutrients

If excessive in media or tissue:	May cause deficiency of:
Ammonium	Calcium
Nitrate	Potassium
Phosphorus	Iron, zinc, copper
Potassium	Magnesium, calcium
Calcium	Magnesium, boron
Magnesium	Potassium, calcium
Manganese	Iron
Iron	Manganese
Zinc	Manganese, iron
Copper	Manganese, iron, zinc

Consider nutrient interactions and proper balance in relation to proper supply. Nutrient supply is important because optimal nutrient ratios in the solution or the plant tissue can be achieved even when both elements are in the deficient or toxic range.

Diagnosing Nutrient Disorders

With nutrient disorders, remember that once visual symptoms are present, marketability of the plants may have already been reduced. Follow rigorous soil-testing programs to detect potential problems before they result in crop losses.

In most cases, symptoms of nutritional disorders occur in defined patterns and are specific for each nutrient. Elements that are mobile within the plant generally induce deficiencies on the older (lower) leaves first, while immobile elements induce deficiencies on the younger (upper) leaves. In some cases, pesticide toxicity or disease symptoms may resemble nutrient deficiencies or toxicities.

In addition, symptoms of nutritional disorders are often species or cultivar dependent. Use soil and tissue analysis to help confirm whether the symptoms are nutritional.

The following symptoms of nutrient deficiency/toxicity (for nitrogen, phosphorus, potassium, magnesium and sulphur) generally affect lower leaves first and may progress to younger leaves as the problem becomes more severe:

Nitrogen

Deficiency

- Leaves turn pale green to yellow.
- Oldest leaves are affected first, but in severe cases, the whole plant may be yellow. Growth is usually stunted.
- Symptoms are very similar to sulphur deficiency.

Excess Ammonium

- Plant growth is restricted.
- Leaves yellow.
- Marginal necrosis occurs.
- The growing point dies.
- High ammonium (generally during the winter months) will interfere with uptake/translocation of potassium, magnesium and calcium, thereby inducing calcium deficiency and reduced potassium and magnesium content of plant tissue.

Excess Nitrate

- Most plants tolerate high nitrate levels without any symptoms.

- Nitrate enhances phosphorus and potassium uptake.
- Excessive nitrate will stimulate vegetative growth and may delay flowering.

Phosphorus

Deficiency

- Leaves appear reddish-purple; lower leaves yellowish.
- Oldest leaves are affected first; necrosis and leaf drop if severe.
- Plant growth is stunted.
- Phosphorus deficiency may be induced under high pH (>7.4) or low pH (<5.0) conditions in soilless media.

Excess

- Phosphorus excess may induce micro-nutrient deficiency symptoms by inhibiting iron, zinc and copper uptake/translocation, possibly due to precipitation of phosphates.

Potassium

Deficiency

- Leaves develop grey or tan areas near the margins.
- Oldest leaves are affected first with characteristic scorching of the leaf tips and around the margins.
- In some plants, spotting or chlorosis between the veins may occur.
- Growth may be bushy.

Excess

- Excess potassium may cause salt burn at very high rates.
- If magnesium levels are marginal, excessive potassium will induce magnesium deficiency.

Magnesium

Deficiency

- Older leaves turn yellow between the veins (interveinal chlorosis).
- In severe cases, younger leaves may be affected and older leaves may develop necrotic spots and then drop off.
- Deficiency can be induced by high potassium levels.

Excess

- Plants can tolerate high levels of magnesium without adverse effects.
- High levels of magnesium can cause deficiencies of potassium and calcium in plant tissue.

Sulphur

Deficiency

- There is a general yellowing of the plant; leaf veins are often yellow.
- Symptoms are similar to nitrogen deficiency.

Excess

- Plants can tolerate high levels of sulphur; however, uptake of molybdenum will be reduced.

The following symptoms of nutrient deficiency/toxicity (for calcium, boron, copper, iron, manganese, molybdenum and zinc) generally affect younger or upper leaves first:

Calcium

Deficiency

- Growing points of plants may die.
- Youngest leaves are affected first.
- Root tips die, and root growth is slow.
- In some plants, leaf edges or tips are yellow or scorched (often termed leaf-edge or leaf-tip burn).
- Deficiency can be induced by high levels of ammonium and excessively wet or dry conditions.

Excess

- Plants can tolerate high levels of calcium without adverse effects.
- High levels of calcium can cause lower levels of potassium and magnesium in plant tissue.

Boron

Deficiency

- Boron deficiency usually occurs on younger plant tissue.
- Young leaves are often dark green, thick and brittle.
- Growing points die and leaves appear small and distorted, with multiple shoot development; "witch's broom" on rose is common.

Excess

- Excess boron can be highly toxic to some plants.
- Toxicity usually occurs on the oldest leaves as a scorching of the margins.

Copper

Deficiency

- Yellowing or dieback of youngest leaves occurs.
- Sometimes yellowing between the veins appears.
- There is a distortion of the leaves with stunted, strap-like growth.
- High levels of phosphorus may induce copper deficiency.

Excess

- Excess copper may induce iron deficiency and cause stunted root systems.

Iron

Deficiency

- There may be yellowing between the veins on the youngest leaves, although veins remain green (interveinal chlorosis); may turn totally yellow to white with necrosis.
- High levels of phosphorus may induce iron deficiency.
- High pH conditions as well as low soil temperatures will cause iron deficiency.

Excess

- Plants can tolerate high levels of iron without adverse effects.
- Chlorotic spots eventually become reddish-brown with eventual collapse of affected tissue.
- High levels may induce magnesium deficiency in some plants.

Manganese

Deficiency

- Manganese deficiency appears similar to iron deficiency.
- Yellowing between the veins of the youngest leaves occurs; usually leaves do not turn white and necrotic.
- Usually only the main veins remain green, causing a fishbone-like appearance.
- Manganese deficiency occurs under high pH conditions and/or low soil temperatures.

Excess

- Reddish-brown to black spots appear on lower leaves between veins; leaves yellow.
- Excess manganese occurs under low pH conditions.

Molybdenum

Deficiency

- Young leaves appear pale, distorted and narrow; whip-tail appearance.
- Young mature leaves may show interveinal chlorosis and in-rolling of leaf margins; ultimately yellowing tissue becomes necrotic.
- In some plants, leaf margins may be scorched.
- Molybdenum deficiency occurs most frequently under low pH conditions.
- Phosphorus and magnesium will enhance uptake, while high sulphur will decrease uptake.

Excess

- Plants can tolerate high levels of molybdenum without adverse effects.

Zinc

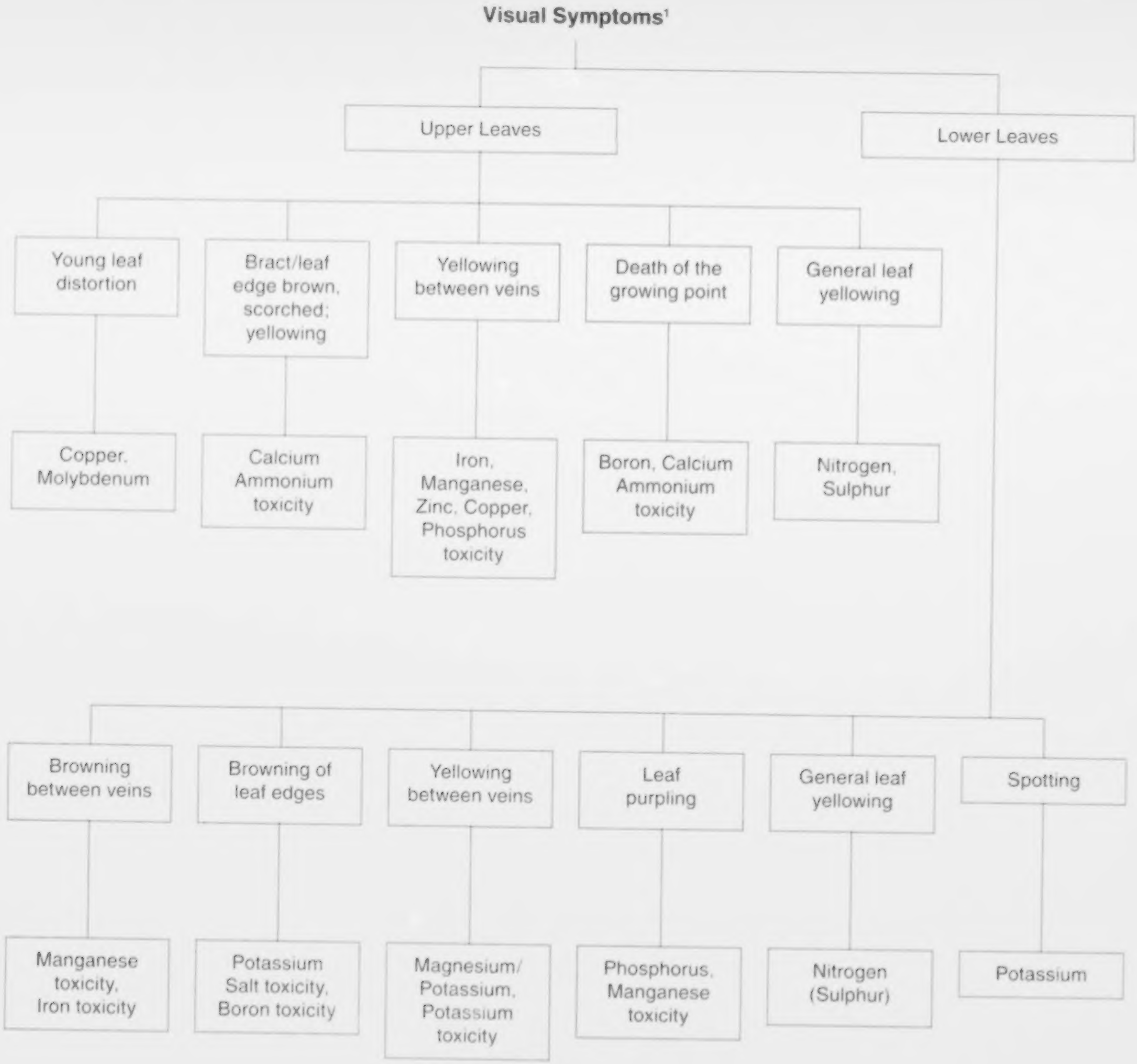
Deficiency

- Younger leaves are affected first and may show signs of yellowing between the veins.
- Other symptoms may include short internodes and rosetting of leaves.
- High levels of phosphorous may induce zinc deficiency.
- Zinc deficiency occurs under high pH conditions.

Excess

- Excess zinc may depress uptake of phosphorus and iron in some plants.
- Excess zinc occurs under low pH conditions.
- The result is reduced root growth and leaf expansion.

FIGURE 2–1. Key to Determining Nutrient Disorders in Greenhouse Crops


Visual Symptoms[1]
Upper Leaves
Lower Leaves
Young leaf distortion
Bract/leaf edge brown, scorched; yellowing
Yellowing between veins
Death of the growing point
General leaf yellowing
Copper, Molybdenum
Calcium Ammonium toxicity
Iron, Manganese, Zinc, Copper, Phosphorus toxicity
Boron, Calcium Ammonium toxicity
Nitrogen, Sulphur
Browning between veins
Browning of leaf edges
Yellowing between veins
Leaf purpling
General leaf yellowing
Spotting
Manganese toxicity, Iron toxicity
Potassium Salt toxicity, Boron toxicity
Magnesium/ Potassium, Potassium toxicity
Phosphorus, Manganese toxicity
Nitrogen (Sulphur)
Potassium

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[1] Symptoms refer to deficiency unless otherwise stated.

3. Integrated Pest Management

This chapter discusses the tools of integrated pest management (IPM). IPM is a pest control philosophy that uses all available control strategies to maintain pest populations of insects, mites or disease organisms below an economic injury level. It does not advocate a continuous pesticide spray program to eradicate pests, but promotes the integration of cultural, physical, biological and chemical control strategies. The concepts of IPM are also further discussed in the context of disease management. See Chapter 6, *Integrated Disease Management*, on page 67.

The routine spraying of pesticides for insurance purposes is no longer likely to achieve effective control. In recent years, this practice has led to a number of problems, including pest resistance, environmental damage and personal health and safety concerns.

Resistance

With fewer pesticides being developed and registered, and more pesticides becoming ineffective due to resistance, growers must use the remaining effective pesticides more efficiently. To reduce the development of resistance, combine pesticide use with other control strategies.

Environmental Damage

Concerns over environmental pollution and groundwater contamination make it important to reduce use of pesticides and their misapplication and to focus on pesticides with a more environmentally friendly profile.

Personal Health and Safety

Potential exposure of applicators and workers to pesticides and pesticide residues in greenhouses means growers should critically evaluate pesticide use in terms of safety during application and frequency of use. Refer to Chapter 1, *Precautions with Pesticides*, on page 1, for more information on working safely with pesticides.

Biosecurity

Biosecurity is the protection of Canada's economy and environment from pests and diseases. It includes reducing the risk of the introduction of new pests and diseases and eradicating or effectively managing the spread of those that have already arrived. As a producer, taking common sense precautions to prevent pests and diseases from entering the farm is a worthwhile investment. In the context of greenhouse floriculture, this should entail good sanitation and IPM practices as described below and in Chapter 6, *Integrated Disease Management*, on page 67. The development of a biosecurity policy for visitors entering the facility also plays an important role in reducing the potential for the introduction and establishment of new pests and diseases.

Monitoring

Careful monitoring provides reliable information to guide an integrated pest management program. The most common greenhouse-monitoring technique is the use of yellow sticky traps (cards or tape) to collect many species of flying insects. These are especially effective for whitefly, thrips, leaf miner, fungus gnats, shoreflies and winged aphids. Note that blue sticky traps have proven to be especially attractive to western flower thrips. However, if a variety of pests are present, yellow traps are a better choice.

When using sticky cards, provide adequate coverage. Use one card every 100–200 m^2 and change the traps regularly. In spring and summer, this usually means changing the cards every week when recording the pest numbers. In winter, when pest numbers are lower, it may be possible to change sticky cards less frequently.

Another important, and often overlooked, monitoring technique is a routine and structured crop inspection program. It is essential for monitoring the presence of plant diseases, mites, wingless aphids or the immature stages of whitefly and leaf miner. Adopt a regular sampling pattern that provides good coverage of the whole greenhouse, including entry points and areas of concern. Concentrate on known susceptible crops or areas within the greenhouse that are known hot spots. Again, keep weekly records.

To monitor for disease, inspect foliage weekly and roots (or, for vegetable crops, the bases of the plants) every two weeks. Check electrical conductivity (EC) and pH biweekly for each crop grown. Detecting diseases and non-flying pests (such as aphids or mites) early makes control easier and may mean containing a problem with only a spot spray or other localized action.

For successful monitoring, do it on a regular basis. Record information so growers can make use of the information in the future. Include:

- date
- pest identification
- location in the greenhouse
- number of insects trapped
- stage of development (e.g., adults, pupae)
- diseases present or suspected
- crop species and cultivar
- control action (pesticide used, rate, area treated, time taken, etc.)
- environmental conditions

Cultural Controls

Sanitation

Sanitation is the first step in any pest control program. If a source of infection or infestation is constantly present due to poor hygiene, pest control programs will be expensive and frustrating. Carry out good sanitation practices in the greenhouse and adjoining structures (boiler rooms, etc.), in the immediate vicinity of the greenhouse and during every stage of crop production.

Proper greenhouse sanitation is a continual, year-round process. Cleanliness on its own may not control pest problems but it is a basic component of any control program and an essential adjunct to other pest management strategies. It is important to:

- Remove dead and dying leaves and flowers. In roses, removal of and disposal away from the greenhouse of all flowers (including those that will not be sold) can play a significant role in control of thrips.

- Remove crop residues and deposit them well away and downwind from the greenhouse.

- Preferably burn residues as permitted by the local municipality or, alternatively, contain and dispose of them.

- Remove all weeds from inside and immediately outside the greenhouse.

- Keep walks and the surfaces of beds clean.

- Check carefully for pest infestations when bringing new stock into the greenhouse.

- Avoid overwintering garden or house plants in the greenhouse, otherwise pests will be maintained for an early invasion of the next crop.

- Maintain good drainage to eliminate puddles and wet surfaces, as these provide ideal breeding sites for fungus gnats and shoreflies and are a possible source of infection for waterborne diseases.

- If the greenhouse is empty between crops (especially likely with greenhouse vegetables, but also possible in some ornamental greenhouses), heat treatment can be an effective way to remove pest infestations. If temperatures are maintained at >40°C and humidity at <50% for 3–4 days, insect and mite pests will be effectively controlled. This is particularly suitable during the warmer months of the year when these temperatures can be achieved by just closing the vents. Note: at higher temperatures, plastic fittings may warp.

- To prevent disease organisms from carrying over on empty structures, heating pipes, walks, benches or equipment, spray with one of these options: See Chapter 6, *Integrated Disease Management* on page 67.

    - A 0.5–1% final solution of sodium hypochlorite bleach. Mix 1 part common household bleach with 10 parts water to obtain a final solution of 0.5%. For a 1% solution, mix 1 part bleach to 5 parts water. Use a higher strength solution (up to 1%) in cases of serious disease outbreaks or when disinfecting wooden benches.

    - Floralife D.C.D., a quaternary ammonium compound with fungicidal and bactericidal activity.

    - Virkon, a disinfectant with fungicidal, bactericidal and virucidal activity.

    - Chemprocide, a quaternary ammonium compound with fungicidal and bactericidal activity.

Managing the Greenhouse Environment

Factors such as light, temperature, humidity, water and nutrients affect not only the plant but also the pests and diseases that afflict them. The use of environmental controls to manage pests is complex because of the simultaneous effects on crop production. Each case is different; look at each carefully. For example, humidity can play an important role in pest and disease development.

Spider mites prefer hot, dry conditions. Increasing humidity by overhead misting can help to retard the development of this pest.

During the winter months, thrips are not particularly mobile. This is probably due to low light levels rather than to low temperatures and it can have implications for monitoring programs. At these times of the year thrips may not be caught by yellow sticky cards, even when thrips are present and actively feeding in the crop.

Air moisture affects the development of diseases such as powdery mildew and *Botrytis*. This makes these problems conducive to treatment by environmental manipulation. See Chapter 7, *Major Greenhouse Diseases* on page 77.

Resistant Cultivars

Many plant species display varietal differences in their susceptibility to insect and disease attack. Breeding of crops can provide growers with cultivars resistant to one or more insects or diseases. For example, greenhouse tomato growers seldom experience problems with *Fusarium* crown and root rot because resistant varieties have been developed. Powdery mildew–tolerant cucumber varieties are increasingly used by greenhouse growers. Although ornamental plant breeders have not taken great advantage of host plant resistance, it offers potential for future advancements in pest management.

In the meantime, growers with pest problems can improve their pest management program by looking closely at the varieties grown and at how these varieties are affected by pests. Use susceptible varieties as indicators for pests and diseases, e.g., the colour of the flower might attract more thrips. Spot-spray the susceptible variety when pests or diseases occur to provide effective control and reduce the amount of pesticide applied. Although market demands determine the varieties grown, it may be possible to eliminate or reduce the amount of a susceptible variety and replace it with a more resistant one.

Soil Pasteurization Methods

Greenhouse media and field soils contain weed seeds, insects, bacteria and fungi that may be harmful to the plants being grown. This includes potting mixes and their components, unless guaranteed sterile or pasteurized by the manufacturer. Pasteurize soil and potting mixes to eliminate these harmful organisms. Ideally, this is accomplished without injuring beneficial soil organisms.

Steam

Steam is the most common heat source for pasteurization. There are different ways of handling steam, depending on the type of crop being grown.

When pasteurizing soil in bulk for vegetable seedlings or potted plants, some growers find it efficient to inject steam into the bottom of a wagon or similar enclosed vehicle.

After cooling, move the pasteurized soil to the area in which it will be used.

Growers of cut flower or vegetable crops follow one of two techniques when steaming soil in beds:

- If ground beds are drained with agricultural tile, it is very simple to inject steam into these tiles and pasteurize the soil on the sides and above them. The top of the tile should be 40 cm below the surface and the rows on 60 cm centres.
- If tiles are not installed, cover the bed with a tarpaulin. Inject steam directly under the tarpaulin through either a canvas hose or a perforated, flexible plastic field tile to ensure even distribution. Soil should be in fine tilth and free from clods and undecomposed crop remains, to allow rapid, uniform penetration of the steam.

If re-using rockwool, note steaming time depends on the wetness of the rockwool and the steam temperature. Steaming at 90°C for 30 minutes should be adequate. Generally, the wetter the rockwool, the longer the steaming period. For this reason, the substrate should be as dry as possible before steaming. Rockwool stacked on pallets without polyethylene bags can be steam-sterilized in two hours. Rockwool wrapped in polyethylene requires five hours of steaming. Rockwool should not be stacked higher than 1.5 m. To stabilize the stacked slabs, place each row at right angles to the previous one. In addition, leave a 2.5 cm space between individual slabs to allow for better steam penetration.

Time-Temperature Relationships to Destroy Undesirable Organisms

The following chart gives the time/temperature relationships necessary to destroy undesirable organisms. It shows that most organisms of concern to growers can be eliminated under ideal conditions of 60°C for 30 minutes.

Weeds (most)	70°C–80°C for 15 min.
Insects and mites	60°C–71°C for 20 min.
Bacteria (most)	60°C for 10 min.
Fusarium	57°C for 30 min.
Botrytis	55°C for 15 min.
Nematodes	55°C for 30 min.
Rhizoctonia	52°C for 30 min.
Sclerotinia	50°C for 5 min.
Pythium	46°C for 40 min.

When temperatures rise above 82°C, beneficial soil organisms begin to be destroyed. If the soil is heated to too high a temperature for too long a time, it becomes sterile. It is then subject to a greater degree of infection than previously, as all beneficial organisms have been destroyed. There are many other undesirable effects of over-steaming, such as:

- excessive ammonia release
- manganese toxicity
- higher total salt levels
- destruction of organic matter

Aerated Steam

Aerated steam is being used more widely today. In this system, steam mixes with air in a chamber. The mixture is used at 70°C to pasteurize soil while avoiding any of the hazards of over-steaming. Unless there are specific problems, a soil temperature of 70°C is adequate for most insect and disease problems.

Electric Soil Pasteurizers

Electric soil pasteurizers are useful when pasteurizing small volumes of soil and where no other method is available. Note that these can overcook the soil very easily. For the soil temperature between the finned heat sources to reach 82°C, the fins themselves must be at a higher temperature.

Chemical Fumigants

Chemical fumigants such as Basamid, methyl bromide, Telone, Vapam and Vorlex can be used for pasteurizing soil for potting or in greenhouse beds or benches. Each of these fumigants has a specific rate and activity against soilborne insects, diseases, nematodes and weeds. Note that some formulations may be less effective against certain types of pests — always read the manufacturer's label. Protect crops in adjoining beds or benches from accidental exposure to escaped fumes.

Fumigants listed in Table 3–1. *Chemical Fumigants for Soil Treatments*, are effective as preplanting treatments for greenhouse soil beds. The amounts shown are for use on 100 m^2:

TABLE 3–1. Chemical Fumigants for Soil Treatments

Control of Nematodes Only	**Rate (per 100 m^2)**
Telone IIB	2.0 L
Telone C-17	2.0 L
Vorlex Plus	2.5 L
Control of Nematodes, Fungi, Insects and Some Bacteria	
Basamid (granular)	3.25–5 kg worked into a depth of 15–23 cm
Vapam (liquid)	10 L
Vorlex Plus (liquid)	6 L
Methyl bromide/ Chloropicrin	Pressurized cans 98%/2%: 7.5–10 kg
	Injectable 68%/31.8%: 2.5–3.65 kg

Notes on Methyl Bromide

Methyl bromide must be applied only by applicators licensed by the Ministry of the Environment! The bromide residue that lingers in the soil after using methyl bromide may reduce the germination and/or growth of salvia, dianthus, ageratum, alyssum, antirrhinum, aster, calendula, celosia, chrysanthemum, cleome, coleus, coreopsis, dahlia, digitalis, godetia, helichrysum, iberis, lobelia, matricaria, myosotis, nemesia, nierembergia, portulaca, salpiglossis, verbena, vinca, and viola.

Do not use methyl bromide prior to planting a lettuce crop or other leafy vegetables.

Weed Control Methods

Control of weeds inside and outside the greenhouse is an important part of any pest management program. Weeds can provide a refuge for insect pests and act as a reservoir for diseases. A 5-metre strip of carefully maintained lawn around and between greenhouses will also decrease the danger of invasion by insects and diseases from outside. Fescue grasses have been shown to be one of the least preferred grasses of western flower thrips, information that may be useful for lawn plantings around greenhouses.

Herbicide application, cultivation and hand weeding are the most practical methods of controlling weeds in and around greenhouses. However, other methods may be useful to reduce the amount of labour required to keep weeds under control.

Steam

As mentioned above, steam used to pasteurize soil will kill weeds and most weed seeds if the soil temperature can be held at 70°C–80°C for 15 minutes. Weed seeds in the outer layer of cooler soil and weed seeds with hard seed coats may not be killed.

Soil Fumigation

Metam sodium (Vapam), dazomet (Basamid) and methyl isothiocyanate (Vorlex) are useful in treating seedbeds and potting soil. They break down in the soil to produce a gas that kills many weed seeds, nematodes and fungi that cause damping-off and other plant diseases.

Methyl bromide is also effective for weed control and general soil sterilizing. It comes as a liquid and forms a poisonous gas when released from the container. Methyl bromide must be used by licensed applicators only, under a gasproof cover, usually plastic.

Herbicides

OMAFRA Publication 75, *Guide to Weed Control*, contains information on herbicides registered for use in Ontario. Treatments listed in the publication are subject to extensive field trials and observation on farms. Herbicides may be particularly useful for weed control outside, but no herbicides are registered for use inside the greenhouse.

There is potential for crop damage if any herbicide is used incorrectly. Always turn fans off so as not to draw herbicides into the greenhouse. OMAFRA Resource Centres and Government Information Centres have copies of Publication 75, *Guide to Weed Control*. Carefully follow the instructions regarding chemicals, safety precautions, calibration, and care and use of sprayers. Where herbicide drift or herbicide damage is suspected, contact an OMAFRA Greenhouse Floriculture Crop Specialist or IPM Specialist.

Where unwanted herbicide residues remain in soil, applying activated charcoal can reduce the problem. The rate varies depending on the type of chemical contaminant and its concentration. A usual range is 0.5–1.5 kg/100 m^2.

Physical Control

Screening

In warmer climates where pests occur outside all year, screening has become an established part of IPM programs. While not as common in temperate areas, screening is becoming more accepted and its value more apparent.

Screening greatly reduces the entrance of common greenhouse pests such as thrips, aphids and whiteflies but also some less common pests such as tarnished plant bugs and European corn borers, which can become major pest problems when pesticide use is reduced (e.g. in biological control programs). Benefits of using insect screening have been demonstrated in Israel and California. In Ontario, growers who have installed screens have reported that pest levels and pesticide use are reduced and effectiveness of pest control (especially biological control) measures improved.

The most important consideration for a grower wishing to screen a greenhouse is to determine which pests need to be excluded. The size of the pest determines the mesh size of the screen that is needed for that purpose. Large mesh sizes of the type normally found in household screens are inadequate for excluding most major greenhouse pests; however, they can be useful in keeping out occasional larger pests such as tarnished plant bugs and lepidopteran (moth) pests. For smaller insects such as thrips, screens must be of a very fine mesh for total exclusion. In cases with multiple pests of concern, mesh size should exclude the smallest of these pests.

Reduction of air flow is a major concern of growers. It can lead to overheating of the greenhouse and stress on the fans (in the case of fan-ventilated greenhouses), which must work harder to pull the same amount of air through the partially blocked vent. Reduced ventilation is a valid concern, but it can be addressed by increasing the surface area of the vent. In many situations this has been done successfully by building a screened framework around the vent opening. The goal is to ensure that the final surface area of the vents provides sufficient air exchange to allow adequate cooling of the greenhouse. There are several methods available for determining the increase in surface area of the vents required for any given greenhouse but factors such as screen mesh size, fan capacity and static pressure drop (the difference in air pressure between inside and outside the greenhouse when the fans are running) are important. Although there are software programs available to assist with these calculations, they can be complicated and are generally best left to screening manufacturers.

The small mesh size means that the screens are very prone to blockage with dust and other deposits, especially in the summer. Such blockage will reduce air flow through the screens and may contribute to excessively high temperature conditions. Therefore, clean the screens regularly. It is also important to incorporate easy access in the design of the screens to facilitate their cleaning. Wash screens from the inside with a high-pressure hose. Do not do this when the fans are operating, because the water will block the pore openings and completely stop air flow, leading to overheating of the greenhouse.

The effectiveness of the screens depends on their ability to exclude flying insects. Tears or holes will permit pest entry; repair these as soon as possible. Small tears can be simply repaired by gluing a piece of screening over the hole.

The cost of screening will depend on several factors: the final screening design, the increase in surface area needed to maintain adequate ventilation, the cost of the screening material, whether roof vents or side vents are to be screened, frequency of replacement, frequency of cleaning, etc. The biggest variable is the difference in cost between installing screens in a force-ventilated, side-vented greenhouse and a passively vented greenhouse with roof vents. Nevertheless, reports from growers who have installed screens over side vents in force-ventilated greenhouses suggest a rapid payback from reduced pesticide costs and improved pest management.

For more information, see OMAFRA Factsheet, *Screening Greenhouses for Insect Exclusion*, Order No. 00-021.

Other Physical Controls

Yellow sticky tape can provide useful additional control of flying insect pests. It works on the same principle as the sticky cards used for monitoring. String tape along beds or benches or hang it vertically within the crop to provide significant supplementary control in conjunction with other control methods.

Biological Control

Biological control is the use of living organisms such as insects, mites, nematodes, fungi and bacteria to control pests such as insects, mites and diseases. Biological control requires very different approaches for vegetables and floriculture. While widespread in greenhouse vegetable crops, biological control is used less in flower crops although grower interest and adoption of the strategy is increasing.

Biological control involves more than just the release of parasites or predators. To be successful, plan at least several months in advance. Follow these steps when considering the use of biological control:

1. Develop a list of resources to help with the program (this may include producers/suppliers of biocontrol agents, other growers, extension specialists, researchers or consultants). Attend courses, seminars and workshops; read magazines and newsletters; and use the Internet to find out as much as possible about biocontrol. Determine which pests to control and which are the most appropriate natural enemies to use.

2. Start in a small and isolated part of the greenhouse if possible to focus more closely on the area being used. This will allow you to become more comfortable with the use of biological control without worrying that the entire crop is dependent on this first use of biological control being successful. In subsequent years, expand the use of natural enemies to include other areas of the operation.

3. If possible, screen the area to be used. Movement into the greenhouse of pests from outside is unpredictable from year to year but can swamp a biocontrol program and make it difficult for the natural enemies to maintain control. With screening, growers need only be concerned about the pests inside the greenhouse. See *Screening* on page 39.

4. Ensure that all staff are aware of the biological control program and why it is being used. They are in the greenhouse every day performing routine crop management tasks and if trained can recognize problems at a very early stage.

5. Many registered pesticides can have long-term (2–3 months) residual impact against natural enemies. Check through pesticide spray records over the previous several months. If such pesticides have been used, wait the appropriate length of time before starting. Use products with less residual impact to control pests and diseases during this period. Effects of many pesticides are listed in Table 3–3. *Reported Effects of Registered Fungicides on Biological Control Agents*, on page 42 and Table 3–4. *Reported Effects of Registered Insecticides/Miticides on Biological Control Agents*, on page 43, and are also available from biocontrol suppliers.

6. Work with the supplier to learn how to check incoming biocontrol agents to determine if they are alive and well. The quality of natural enemies produced by the major insectaries is excellent but occasionally problems can arise in shipping. Suppliers need to know about any problems in quality so the causes can be identified and corrected.

7. Follow instructions in storing and releasing the natural enemies. Many can be stored for only a short period of time under fairly specific conditions.

8. Monitor the populations of natural enemies and the progress of the biocontrol program. This is as important as monitoring the pest populations.

   - Use sticky cards to monitor flying insects, especially the parasitic wasps. Be aware however, that some natural enemies (e.g., *Eretmocerus* for whitefly control) are highly attracted to yellow, and too many sticky cards may be detrimental to the program.

   - Check the impact of the natural enemy on the pest; e.g., parasitism of whitefly by *Encarsia* and aphids by *Aphidius* parasitic wasps is easily checked.

   - Visually inspect the crop for natural enemies such as predatory mites, which don't fly. Inspect the crop especially in areas of highest pest numbers.

   - Regularly monitor pests to determine if populations are decreasing.

9. Use compatible pesticides if necessary. Such pesticides should be identified prior to starting a program so they are available and can be used if necessary. See tables below or refer to lists available from suppliers.

10. Be patient. It takes some experience to understand a system of biocontrol. Ask others with experience if the program is not progressing as expected.

Commercially produced biocontrol agents are available for all the major greenhouse insect and mite pests, but not yet for diseases. For more details about the implementation of biological control or about supplies of parasites/predators, consult an OMAFRA greenhouse pest management specialist, crop specialist or an industry consultant.

Use caution when using pesticides with biocontrols, since most pesticides are harmful to natural enemies. Application of just one harmful pesticide can prevent any further use of biocontrol agents for an extended period of time. See Tables 3–3 and 3–4 for more information.

TABLE 3–2. Biocontrol Agents for Principal Greenhouse Pests

Pest	Biocontrol Agent
Whitefly (*Trialeurodes vaporariorum* and/or *Bemisia argentifolii*, *Bemisia tabaci*)	*Encarsia formosa*[1] *Eretmocerus eremicus*[1] *Eretmocerus mundus*[1] *Amblyseius swirskii*[2] *Delphastus pusillus*[2] *Dicyphus hesperus*[2]
Spider mite (*Tetranychus urticae*)	*Phytoseiulus persimilis*[2] *Amblyseius fallacis*[2] *Amblyseius californicus*[2] *Feltiella acarisuga*[2] *Stethorus punctillum*[2]
Western flower thrips (*Frankliniella occidentalis*)	*Amblyseius cucumeris*[2] *Amblyseius swirskii*[2] *Amblyseius degenerans*[2] *Orius* spp.[2] *Hypoaspis* spp.[2] *Atheta coriaria*[2] Nematodes – *Steinernema feltiae*
Aphids, including: green peach aphid (*Myzus persicae*), melon aphid (*Aphis gossypii*), foxglove aphid (*Aulacorthum solani*), potato aphid (*Macrosiphum euphorbiae*)	*Aphidius* spp.[1] *Aphelinus abdominalis*[1] *Aphidoletes aphidimyza*[2] Ladybeetles (*Harmonia* and *Hippodamia*)[2] Lacewings[2]
Fungus gnat (*Bradysia* and *Corynoptera* spp.)	*Hypoaspis* spp.[2] Nematodes — *Steinernema* spp. *Atheta coriaria*[2]
Leafminer (*Liriomyza trifolii*)	*Diglyphus isaea*[1] *Dacnusa sibirica*[1]

[1] Parasitoid: Usually requires only one host for completion of development, often killing it by living on or in its body.

[2] Predator: Feeds on its prey (pest) by catching it, but otherwise lives independently of it. It must consume more than one individual to reach maturity.

TABLE 3-3. Reported Effects of Registered Fungicides on Biological Control Agents[1,2,3]

Fungicides	*Encarsia formosa* and *Aphidius*	Phytoseiulus persimilis	*Amblyseius cucumeris* and *Hypoaspis*	Aphidoletes aphidimyza	*Orius* spp.
Aliette	—	S	S	I	—
Botran	S	S	S	S	S
Captan/Maestro	S	S	S	S	S
Compass	—	S	—	—	—
Daconil	S	S	I	S	S
Decree	—	—	—	—	—
Folpet	S	S	S	—	S
Meltatox	S	S	—	—	—
Milstop	—	—	—	—	—
Mycostop	S	S	S	S	S
Nova	S	S	S	—	S
Phyton 27	S	S	S	S	S
Quintozene	—	—	—	—	—
Rootshield	S	S	S	S	S
Rovral	S	S	S	S	S
Senator	S	H (14–21)	H (14–21)	S	S
Subdue	I	I	I	S	—
Truban	S	S	S	S	—

[1] Numbers in parentheses refer to residual toxicity to biological agent, in days. S = Safe; H = Harmful; I = Intermediate; "—" means no data is available, so presume toxic unless otherwise proven.

[2] This table serves only as a guide to possible effects of pesticides. Variations in toxicity may occur under varying conditions.

[3] This table was compiled from information produced by *Applied Bionomics Ltd.* and *Koppert Biological Systems.* Where discrepancies existed in the available information, it provides a range of residual toxicities or the more conservative figure.

Chemical Control

Pesticides will remain an important component of greenhouse pest management programs, however, growers must carefully monitor their use. For the reasons noted above, make the best possible use of those that are available.

Resistance

Pests can develop resistance to any pesticide if used incorrectly or too often. Although there are benefits from new product registrations, do not simply wait for the latest advance in pesticide chemistry. The long-term problems presented by pesticide resistance far outweigh the short-term gains of a new product if it is used incorrectly.

Resistance is the evolutionary adaptation of a population to survive a pesticide dose that is lethal to most of its individuals. It is an inherited trait, which is passed onto future generations. While resistance does not develop within an individual during its lifetime, it usually exists naturally in some individuals in a population but at very low frequencies (too low to be measured or noticeable). The frequency of resistance increases when pesticide exposure kills susceptible individuals while allowing successively greater numbers of resistant individuals to survive and reproduce, passing on their resistance to their offspring.

Resistance management programs aim to reduce the pressure applied to pest populations by pesticides. Use diverse control methods to reduce the need for pesticides. There are several ways to do this, mirroring the approach of IPM programs. Growers using IPM programs, good monitoring techniques and cultural, biological, and physical controls are practising resistance management at the same time.

Note that when pesticides are used in an IPM program, the rate at which resistance develops increases if one class of pesticides (e.g., organophosphorus, synthetic pyrethoid, carbamate) is used for a prolonged period. How quickly resistance develops depends on a number of factors. It may be a short as 1–2 years or could take place over a period of 10 years or more depending on factors such as:

- the pest being controlled
- the pesticide being used
- the pesticide history of the greenhouse

TABLE 3–4. Reported Effects of Registered Insecticides/Miticides on Biological Control Agents[1, 2, 3]

Insecticides	*Encarsia formosa* and *Aphidius*	*Phytoseiulus persimilis*	*Amblyseius cucumeris* and *Hypoaspis*	*Aphidoletes aphidimyza*	*Orius* spp.	Bumblebees
Avid	H (7-21)	H (14)	H (14)	H (?)	H (21)	Remove hive
Citation	S	S	S	S	S	Cover hive
Confirm	—	I	—	—	—	Cover hive
DDVP/Sanex Vapo	H(7)	H(3)	H(3)	H(3)	H(7)	Remove hive
Decis	H(56–84)	H(56–84)	H(56–84)	H(56–84)	H(56–84)	Remove hive
Dibrom	H(7)	H(3)	H(3)	H(7)	H(3)	Remove hive
Dimilin	S	S	S	S	H	Do not use
Dipel	H(3)	S	S	I	S	Cover hive
Dyno-Mite	H(3—4)	I	H (0)	—	—	Remove hive
Endeavor	I(3-4)	I	S	—	S	Cover hive
Enstar II	I	S	S	—	—	Cover hive
Floramite	S	S	S	S	S	Safe to use
Intercept	S	S	S	S	H(28–42)	Do not use
Ins. Soap	H(0)	H(0)	H(0)	H(0)	H(0)	Cover hive
Kelthane	H(14)	H(14)	H(30)	H(4)	I	Cover hive
Malathion	H(56–84)	H(7–14)	H(56–84)	H(70)	H	Do not use
Nicotine (F)	I(3)	I	H(1)	H(1)	I	Remove hive
Oil (Refined mineral)	H(0)	H(0)	H(0)	H(0)	H	Cover hive
Orthene	H(56–84)	H(21–28)	H(56–84)	H(56–84)	H	Do not use
Pounce	H(56–84)	H(56–84)	H(56–84)	H(56–84)	H(56–84)	Do not use
Pirliss	I(3–4)	I(3–4)	I(3–4)	H(7)	S	Cover hive
Success	H (14)	H (7)	H (7-14)	—	—	Remove hive
Thiodan	H(56–84)	H(4–14)	H(42–70)	H(56–84)	H	Do not use
Tristar	H (>14)	S	—	—	H (>49)	Remove hive
Trumpet	H(21)	H(21)	H(21)	H(21)	H	Do not use
Vectobac	S	S	S	S	S	—

[1] Numbers in parentheses refer to residual toxicity to biological agent, in days. S = Safe; H = Harmful; I = Intermediate; "—" means no data is available, so presume toxic unless otherwise proven.

[2] This table serves only as a guide to possible effects of pesticides. Variations in toxicity may occur under varying conditions.

[3] This table was compiled from information produced by *Applied Bionomics Ltd.* and *Koppert Biological Systems*. Where discrepancies existed in the available information, it provides a range of residual toxicities or the more conservative figure.

- how often the pesticide is applied
- the introduction of pests from other facilities
- what sort of resistance management strategies are in place

To slow the rate of resistance development, rotate pesticide classes every few weeks or for a period equal to the generation time of the pest being controlled. See Chapter 8, *Pesticide Toxicity and Activity*, on page 91 for pesticide classes.

Pesticides must be used responsibly so that new products do not lose their effectiveness within a year or two of registration.

Pesticide Application Effectiveness

The most common cause of control failure is *not* resistance. Several other factors determine the effectiveness of a particular pesticide application:

- Ensure that pesticide rates are calculated and measured accurately.
- Good coverage is needed for good pest control. Simple changes such as walking more slowly through the crop when applying pesticides or walking every aisle instead of every other one, can significantly improve performance.

- Maintain spray equipment in good condition, changing spray nozzles on a regular basis. Older nozzles become worn, which can alter spray pattern and droplet size.

- Consider using different application technologies. High-volume, low-volume and electrostatic-spray application all have their place in the greenhouse for appropriate purposes.

- Perhaps the biggest improvement in pesticide application comes from timing and targeting sprays more effectively. To do this, implement an IPM program that provides the information required to decide when, where and why a pesticide application is needed. Sprays can then be applied where most needed (e.g., as spot sprays), when they will provide optimal control and directly at the appropriate pest at the correct life stage.

- Pesticide effectiveness will vary (often considerably) from greenhouse to greenhouse, depending on factors such as the usage history of a particular product, the method of application, the time of application and the water quality.

Water for Pesticide Application

It is very important to neutralize alkaline water when using the water for pesticide spray-tank mixtures. Adjust water pH to 5.5–6.0; at pH greater than 7, the pesticide may degrade rapidly.

Because many pesticides breakdown in alkaline water, try to use pesticides diluted with alkaline water (pH greater than 7) immediately.

However, spraying immediately is not always possible. Note that any delay in applying spray mixtures will result in pesticide loss due to decomposition and, possibly, a corresponding decrease in control. To avoid this, neutralize alkaline water before adding any pesticides. Dissolve ammonium dihydrogen phosphate at the rate of 50 g/100 L water first, then add pesticides.

The rate of decomposition depends on the pesticide, the concentration of pesticide in the tank (dilution factor) and the temperature of the water.

The phosphate is not always necessary, but this practice provides insurance against pesticide loss. Phosphate costs substantially less than pesticides and the added phosphate will be available as a foliar nutrient.

Water-soluble fertilizers are used occasionally with pesticides as a tank mixture. In this case, it is important to choose acidic fertilizers, which make the addition of ammonium dihydrogen phosphate unnecessary. Do not use alkaline fertilizers for this purpose; the amount of phosphate recommended above will be insufficient to neutralize the water, and pesticide decomposition may increase.

Pesticide Compatibility

Pesticides recommended in this publication are for individual application to a crop. Before mixing pesticides, read the product labels carefully for compatibility statements or contact the supplier. Avoid mixing Emulsifiable Concentrate (EC) formulations. Herbicides should never be mixed with fungicides and insecticides; apply with spray equipment reserved for herbicide use only.

Types of Pesticide Application

Spraying

Spraying is one of the most widely used and effective methods of applying pesticides. Clean and pressure-maintain nozzles to achieve a fine spray that will result in uniform coverage when the mixture is applied up to the point of runoff. Complete coverage is the objective; spray both the lower and upper leaf surfaces thoroughly.

Soil Drenches

Soil drenches are used for both disease and insect control and involve the application of the pesticide to the root zone. The amount of pesticide added varies depending on the pot size and volume of the growing medium but to thoroughly wet the growing medium in a 15 cm pot, requires approximately 150–180 mL. For soil beds, apply 12 L of drench per m^2. Be aware that not all pesticides require that the medium be completely wet, so follow the label directions carefully.

For disease control, drenches should not replace a thorough greenhouse pasteurization program but they are useful for preventing recontamination or eliminating pathogens in the soil or the basal parts of the plant. Use a root inspection-monitoring program as the first line of defence against root diseases.

Some drenches are taken up from the soil by plant roots and distributed throughout the plant. This is described as systemic action, and the whole plant is effectively treated against the pest or disease being targeted.

For insect control, drenches can be used either for soil dwelling insects such as fungus gnats and shore flies, controlling them by contact action; or for foliar feeding sucking insects such as aphids and whiteflies using systemically active products.

Thermal Fogs

Thermal fogs are produced by several kinds of machines. These machines all use heat from different sources to vaporize the pesticide. Fogging can be a very efficient method of pesticide application provided the operator follows the basic instructions.

Granular Application

Several types of applicators are available for applying granular pesticides. Be sure the applicator does not grind or fracture the granules.

Insecticidal Smoke Applications

Smokes are a very simple but effective means of pesticide application. There is no equipment involved; containers are simply placed on the path and lit. Do not use smokes in very old, poorly-sealed greenhouses or during high winds.

Ultra-Low Volume

There are several types of ultra-low volume (U.L.V.) applicators available. They atomize the pesticide solution into an extremely small particle size (7–20 microns). They distribute pesticide through the greenhouse by a forced-air fan system.

Electro-Static Sprayers

Electro-static sprayers (E.S.S.) add an electrical charge to the fine spray particles. This enhances plant coverage by the pesticide and reduces drift.

Seed Treatments

Seed treatments are pesticides which coat the seed providing protection against pests or diseases during germination and early growth stages of the plant. Note precautions when using seed treatments in Chapter 1, *Precautions with Pesticides*, on page 1.

Wetting Agents

Wetting agents are classified as pesticides and need to be registered as such. In the following discussion, the term "wetting agent" includes spreaders, stickers and surfactants, although these terms have slightly different technical meanings.

Water will not always spread evenly over a surface. Its hydrophilic (water repellent) nature creates a high surface tension so that, when placed on a leaf (hydrophobic) surface, it forms large droplets that easily roll (with the pesticides) off the leaf and onto the ground.

Reducing the water's surface tension by adding a wetting agent allows the water to make better contact with the leaves. Consequently, the pesticides spread more evenly over the leaf surface. Most pesticides are formulated with a wetting agent in them. However, in some cases (due to air or water temperature, water hardness, type of leaf surface, stage of plant growth and/or the type of formulation), the amount may not be adequate. Consult the label for specific recommendations.

A simple method of determining if the amount of wetting agent present is sufficient is to spray about 3 metres of bed area. Examine both the upper and lower surfaces of leaves at different growth stages for evidence of uniform wetting. If wetting is not uniform, add 125 mL of spreader per 1000 L of spray. Spray another 3 m of the bed and re-examine. Continue until wetting is satisfactory. Wetting agents help the spray solution to wet powdery mildew mycelium, improving control. However, an excessive amount of wetting agent can cause plant damage, excessive foaming which will cause pumping problems or runoff resulting in poor control.

4. Major Insect and Mite Pests

Quarantine Pest Problems

This chapter describes the most common insect and mite problems in greenhouse ornamental production. However, it is important to realize that some of the most destructive pests and diseases are very infrequently found but when they are, the impact can be devastating. A quarantine pest is "a pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled (FAO, 2004)." Some of these pests or diseases are known to be a potential risk and are regulated by the Canadian Food Inspection Agency (CFIA). Other pests may have no known potential for damage until they occur, at which time CFIA will decide on the risk they present. If found, regulated pests by law (*Plant Protection Act*) must be reported to CFIA who will decide what action must be taken to address the problem. Although this action can have serious financial impacts on individual growers, it is important to the industry that growers report suspected problems. Failure to do so could threaten the export of ornamental plants to countries such as the United States. Known quarantine pests are noted in Chapter 5, *Occasional Pests*, on page 59. For more information on regulated pests and diseases see the CFIA website *www.inspection.gc.ca/english/plaveg/protect/listpespare.shtml* or contact your local CFIA office. See Appendix D, *Other Contacts*, on page 146.

Thrips

Description and Life History

Thrips are tiny, slender, agile insects about 1.5–2 mm in length when fully developed. Adults vary in colour from dark brown or black through to yellow or straw-brown. Immatures are usually white or yellow with red eyes. Several thrips species, including eastern flower thrips, onion thrips, and western flower thrips (WFT), are found in the greenhouse.

All thrips have a similar life cycle. The adult female lays tiny white eggs inside the leaf tissue. The eggs hatch in five to seven days and the white larvae emerge to feed on the leaves and petals. They pass through two larval stages, a prepupal stage and a pupal stage (on the soil or plant) before becoming adults. Adults can live up to seven weeks. A new generation may occur every 20–35 days, depending on the temperature.

Damage

Piercing/sucking mouthparts cause white streaked areas on leaves or translucent spots on flower petals. Feeding is characterized by tiny, black, fecal deposits on leaf surfaces. Adult females can also damage fruit quality, e.g., tomato, by laying eggs in the fruit. Small whitish "ghost-spots" appear where eggs are laid, which causes uneven fruit ripening.

Thrips also rapidly develop pesticide resistance. They can carry impatiens necrotic spot virus or tomato spotted wilt virus (INSV/TSWV), which can devastate many common greenhouse crops. Proper diagnosis is essential, as these viruses have a wide host range and produce a wide variety of symptoms. Control of INSV/TSWV is difficult, involving thrips population management, removal of infected plants and good weed control inside and outside the greenhouse. Use indicator plants such as petunia or fava bean for early detection of INSV/TSWV.

Control Strategies

Employ a regular monitoring program using yellow or blue (both very attractive colours to WFT) sticky cards and regular crop inspection.

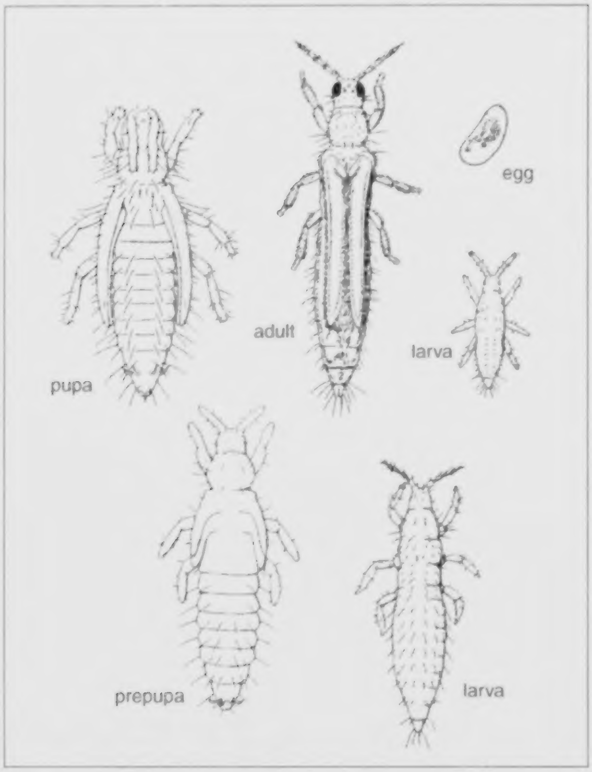
All stages of the thrips (except eggs) can be detected by tapping buds or flowers over a sheet of white paper and checking the thrips that fall.

Biological Control

A number of biological control agents are available for thrips control: the predatory mites *Amblyseius cucumeris*, *Amblyseius swirskii*, *Amblyseius degenerans* and *Hypoaspis*; the predatory bug *Orius insidiosus*; and the predatory rove beetle *Atheta coriaria*.

Gain the best control by using more than one in combination. Introduce them when pest levels are low, using high enough introduction rates to achieve success.

FIGURE 4-1. Western Flower Thrips



Amblyseius cucumeris
This buff-coloured predator feeds mainly on the first nymphal stage of thrips.

Amblyseius cucumeris is usually shipped to growers in a mixture that includes bran and bran mites. The bran provides food for the bran mites, which are themselves food for the predatory mites. The bran/mite mixture is available in small sachets or in containers from which the mixture is sprinkled directly on to the crop. The sachets serve as small rearing units from which predatory mites emerge over several weeks.

Always examine the bran mixture prior to use. It should not be mouldy or smell of ammonia and live predatory and bran mites should be visible. Healthy predatory mites move rapidly, whereas bran mites move more slowly. Hang sachets in sheltered positions to minimize dehydration of the bag contents. Rates of application of this predator vary with crop and level of thrips infestation. Contact the biological control supplier, consultant or OMAFRA IPM specialist for suggested rates.

Amblyseius swirskii
This predatory mite is very similar in size and appearance to *A. cucumeris*. Permits for its import to Canada were only obtained in the spring of 2006, so experience with its use is still limited.

It is sold in the same types of formulations (bulk mixtures and slow release sachets) and feeds on the same life stages of the thrips. It is reported to be more effective than *A. cucumeris* especially on crops that produce pollen such as greenhouse peppers, however, some early experience in ornamental crops such as gerbera is also promising. It is also effective against other pests such as whitefly.

Contact the biological control supplier, consultant or OMAFRA IPM specialist for suggested rates.

Amblyseius degenerans
This predator differs from *A. cucumeris* in appearance and in being able to tolerate less humid conditions. It is dark, very agile and reproduces very well on pollen.

It can be reared on castor bean plants, which can be release points for the predator within the greenhouse. It performs best in situations where it has a pollen source (e.g., greenhouse pepper) to encourage establishment. Because of this, it is unlikely to be the best option for most floricultural crops.

Hypoaspis
This soil-dwelling mite provides additional thrips control by feeding on pupae in the crop media. For more details, see *Fungus Gnats*, on page 54.

Orius insidiosus
The minute pirate bug, *Orius insidiosus*, is a winged predator that consumes all mobile stages of thrips. Adults are black with white and cream markings on the wings. The youngest nymphs are yellow and the oldest are a dark mahogany brown.

Orius also feeds on pollen, spider mites, aphids, whiteflies, moth eggs and young caterpillars. However, its preferred food source is thrips.

Pirate bugs are sensitive to day length. Do not release them in greenhouses before mid-March unless at least 13 hours of light is available, for example if supplemental lighting is used.

Atheta coriaria
This soil-dwelling beetle was originally developed for control of fungus gnats and shoreflies, but also feeds on thrips pupae in the soil. For more information see *Fungus Gnats*, on page 54.

Chemical Control

Chemical control of WFT can be difficult. They tolerate most pesticides and feed deep within the flower head or on developing leaves. This makes them a difficult target for insecticides, so thorough coverage is essential. General recommendations regarding pesticide use for thrips control are as follows:

- At the action threshold (when thrips population levels dictate spraying to prevent economically damaging numbers from appearing), spray four to five days apart for three consecutive applications.
- Follow resistance management guidelines on the label.
- Rotate chemical classes and use a single chemical class only for the duration of the thrips' life cycle. This generally means using a different class every two to three weeks depending on time of year. Generation times are longer at cooler temperatures.
- When there is a limited number of effective products, use sparingly and only at critical times of the year or crop. Use IPM strategies to reduce pesticide use and the potential for resistance development.
- Apply pesticides in early morning and late afternoon, when flight activity of thrips is at a peak. This increases exposure of the thrips to the pesticides.

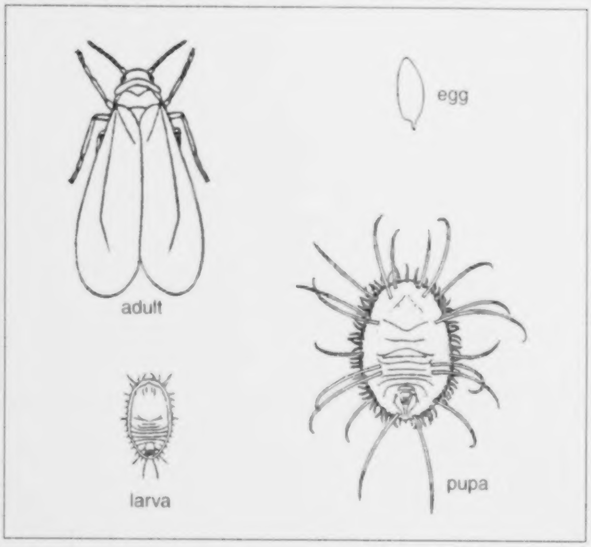
Whiteflies

Description and Life History

Adult whiteflies are small, winged, white insects about 1.5–2 mm long. They lay eggs on the underside of the youngest leaves and are too small to be seen clearly without a microscope. A female whitefly may lay up to 300 eggs during her lifetime and can live up to two months. The nymphs or crawlers hatch in 5–10 days, are flat and scale-like and crawl around for a short while before becoming immobile.

Adults emerge after three nymphal stages and one pupal stage. Old pupal skins and adults may be found on the underside of lower leaves, which may have symptoms of wilt. On average, the whitefly completes its life cycle in 35 days at 18°C and in 18 days at 30°C. Whiteflies have no special overwintering stage and can usually survive if plant life is available.

FIGURE 4-2. Greenhouse Whitefly



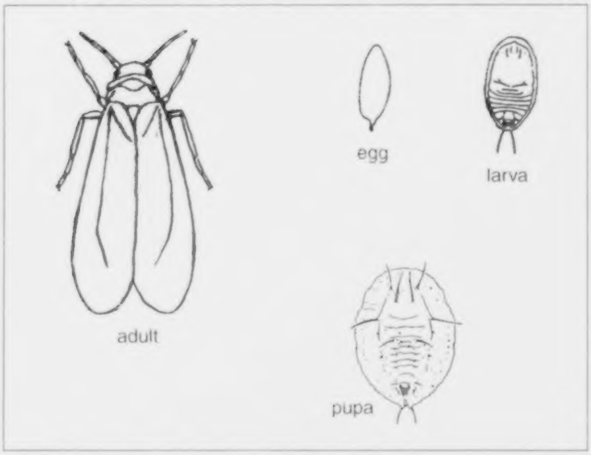
Species of Whiteflies

Two whiteflies concern growers in Ontario: the greenhouse whitefly (GWF) and the silverleaf whitefly (SLWF). The GWF and SLWF adults look very similar, albeit with some differences:

- The SLWF is slightly smaller than GWF, and its body is more yellow.
- At rest, SLWF holds its wings tent-like above its body, while the GWF holds them flatter and more parallel to the surface on which it is resting.
- The major diagnostic differences between GWF and SLWF appear in the pupal stages. The GWF pupa is raised off the leaf surface and is surrounded by a fringe of hairs, while the SLWF pupa sits flat on the leaf and does not have a fringe. These features are best seen with a microscope.
- SLWF fly in a more direct manner, while the GWF assume a more haphazard flight pattern.
- In Ontario, SLWF is most commonly found on poinsettia although it can also establish on other crops.
- Two biotypes of SLWF have been found in North America. The B biotype has been a pest in greenhouses since the mid to late 1980s and is found most often on poinsettia. The Q biotype is Mediterranean in origin and was found for the first time in North America in 2004. It is reported to rapidly develop resistance to pesticides. It is also reported to have a wider host

range than the B biotype and to be better as a vector of a range of plant viruses.

FIGURE 4–3. Silverleaf Whitefly



Damage

Piercing/sucking mouthparts allow whiteflies to remove sap from the plant, reducing plant vigour.

Whiteflies excrete large amounts of a sugary substance called honeydew. Honeydew promotes the growth of a black sooty mould fungus on leaf and fruit surfaces, reducing photosynthesis and fruit quality respectively. The sooty mould itself does not damage the plants.

The SLWF is reported to transmit over 60 viruses and the GWF has been associated with the spread of beet pseudo-yellows virus in cucumbers.

Control Strategies

Implement a routine monitoring program using yellow sticky cards and plant inspections.

Use host plants more attractive to whiteflies than the main crop as an early detection tool or as a trap plant. Plants such as eggplant and tomato may be useful for this purpose.

Identify the whitefly species present on the crop.

React promptly when whitefly adults are observed on either on cards or on terminal leaves.

Maintain good weed control inside and outside the greenhouse.

Biological Control

Three parasitic wasps — *Encarsia formosa*, *Eretmocerus mundus* and *Eretmocerus eremicus* — are commercially available for whitefly control. *Encarsia formosa* is more effective against GWF but provides some control against SLWF. *Eretmocerus mundus* is specific and very effective against SLWF. *E. eremicus* is more effective against SLWF but can also provide good control of GWF. The predatory mite *Amblyseius swirskii* is reported to be very effective against whitefly (all species) as well as thrips. A small, black beetle, *Delphastus pusillus* is also available commercially but is likely to be effective only where there are heavy populations of whitefly (a situation that most growers would want to control more quickly with pesticides).

Good sanitation, weed control and low whitefly numbers to begin with are essential for successful biological control of whitefly.

Encarsia formosa

About 0.6 mm long, adult wasps are parasites that kill whiteflies mainly by laying eggs into the immature stages or scales (mostly the third and fourth larval stages). Adult *Encarsia* can live for a few days to a month depending on the temperature. Females lay 50–350 eggs in their lifetime. A greenhouse whitefly scale turns black 10–14 days after being parasitized. On average, the adult wasp emerges two weeks later. When the adult develops fully, it cuts an opening in the top portion of the black scale before emerging. Parasitized SLWF turn tan-brown and are less easily noticed. For biological control of SLWF, *Eretmocerus* offers a better alternative.

To use *Encarsia* successfully:

- Avoid pesticides with long residual effects for at least three months before the initial release. Refer to Tables 3–3 and 3–4, on pages 42 and 43.
- Monitor the crop for whitefly presence at all production stages and follow population level trends to place and time parasite releases more accurately.
- Introduce *Encarsia* at the first sign of whitefly or preventitively before whiteflies are detected. If whiteflies are present before the release of *Encarsia*, knock back populations with a low-residual pesticide.
- Don't use *Encarsia* between December and February without adjusting light and temperature conditions to suit the parasite. Even so, these two months are the

most difficult time to establish *Encarsia* in the greenhouse.

- Distribute *Encarsia* in shaded parts of the plant where the parasites are protected from direct sunlight.
- Distribute cards relatively evenly but place more in areas where whiteflies have been observed. Achieve more distribution points by purchasing cards with fewer parasitized scales per card.
- Don't remove leaves with immature parasitized scales during deleafing or pruning operations in vegetable crops such as tomato. Such removal slows buildup of *Encarsia* numbers and parasitism rate.
- Continue introducing *Encarsia* until approximately 80% of the scales on older leaves are black. During warmer months when whiteflies migrate into the greenhouses, maintain or increase introductions.

Eretmocerus mundus and *E. eremicus*

Adults are about 0.6 mm long and yellow. They lay eggs under the whitefly larvae, preferably second or third stage. This wasp has a sex ratio of 1:1 (male:female). Introduction rates refer to the number of females introduced. This is different from *Encarsia*, where all individuals are female. The effectiveness of this wasp is due to both host feeding by the adult and parasitism. The parasitized whitefly pupa is a yellowish-brownish colour (for both GWF and SLWF). *E. mundus* is specific to *Bemisia* (SLWF), whereas *E. eremicus* will feed on both whitefly species. However, *E. mundus* seems to offer better control of SLWF than *E. eremicus*.

Amblyseius swirskii

This predatory mite is very similar in size and appearance to the thrips predator *A. cucumeris*. It also feeds on thrips, however, unlike *A. cucumeris*, it is also a very effective whitefly predator. Permits for its import to Canada were only obtained in the spring of 2006, so experience with its use is still limited.

It feeds on whitefly eggs and crawlers. As a result, it is very compatible with the parasitic wasps used for whitefly control, which target later life stages. It is sold in both bulk mixtures and slow release sachets.

It is reported to be very effective especially on crops that produce pollen such as greenhouse peppers, however, some early experience in ornamental crops such as gerbera is also promising.

Contact the biological control supplier, consultant or OMAFRA IPM specialist for suggested rates.

Delphastus pusillus

Delphastus is a predatory beetle. Both adult and larval *Delphastus* feed on whiteflies, particularly on the eggs and nymphs. *Delphastus* are reported to avoid parasitized scales, feeding on principally the non-parasitized scales. This behaviour makes *Delphastus* compatible with *Encarsia*. Use these beetles to supplement the activity of *Encarsia* in reducing whitefly populations. Adult *Delphastus* live for six to nine weeks. They are reported to require a minimum diet of 10 whitefly eggs/day to reproduce.

Physical Control

Sticky Traps

Use yellow sticky traps in various forms to trap large numbers of adult whiteflies. Large, yellow sticky boards or 30 cm-long yellow sticky tapes can be placed in "hot spots" at a rate of about one per plant. Alternatively, hang yellow sticky tape between posts along plant rows. Such tapes will also trap fungus gnats, shoreflies, *Aphidius* spp. and *Encarsia*, especially under low whitefly populations. Be careful in using large quantities of sticky tape in conjunction with parasitoids, especially *Eretmocerus*, which is highly attracted to yellow.

Vacuuming

Hand vacuum adults in "hot spots" to rapidly remove adult whiteflies.

Insect Barriers

Install fine screens over vents and doorways to significantly reduce migration of outdoor populations into greenhouses. Where whiteflies move in from adjacent field crops (e.g. field tomato) in large numbers at certain times of the year (e.g. during harvest), consider screening as a first line of defence.

Chemical Control

Rational and judicious pesticide use requires a regular monitoring program, using action thresholds, rotating chemical classes and incorporating all available non-chemical control strategies.

Whiteflies have developed resistance to many pesticides. Judicious use will extend the effective life of pesticides while delaying the buildup of resistance.

When using a systemic insecticide such as Intercept, ensure that it is applied correctly. The root system should be well developed and the plant actively growing. If the plant is to be pinched, apply the product 10–14 days afterwards. Limit watering for a week after application to reduce the amount of leachate; Intercept is very water-soluble and will be easily leached from the pot.

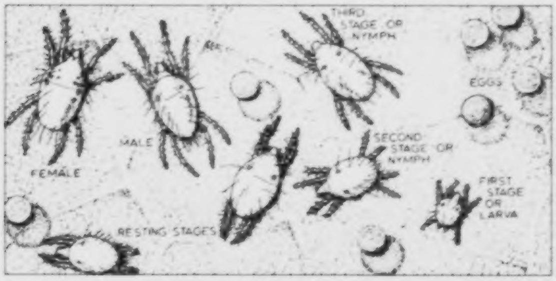
Two-Spotted Spider Mite

Description and Life History

The two-spotted spider mite (TSSM) attacks many greenhouse crops. The eight-legged female adult is approximately 0.5 mm long with a rounded abdomen. The male is distinguished from the female by its smaller, narrower body and pointed abdomen. Adults range from pale yellow to orange to brown. The overwintering or diapausing stage is reddish-orange. Day lengths of 12 hours and less, decreasing temperatures and a deteriorating food source will induce diapause in spider mites. During diapause, spider mites can tolerate very low temperatures. A short spell of heating is not sufficient to break its diapause.

Close examination of leaf undersurfaces will show the mites to be miniscule moving dots. The two dark spots on the body of TSSM are the gut contents showing through the transparent body. After mating, each female mite lays about six pearly white eggs a day. Over an average lifetime, a female lays 100 or more eggs on the undersurface of foliage. Newly hatched mites pass through the typical six-legged larval stage and eight-legged protonymph and deutonymph stages. The last of these is an immobile resting stage, very tolerant of miticides. The life cycle from egg to adult ranges from 23 days at 15°C to just four days at 32°C. Development is fastest under hot, dry conditions.

FIGURE 4–4. Two-Spotted Spider Mite



Damage

All active stages of the two-spotted spider mite feed by piercing the lower epidermis of the leaf with sucking mouthparts. The feeding injury starts as a yellow "stippling." As mite numbers increase, the entire leaf appears stippled or light-coloured on the upper surface. Very heavily infested leaves become yellow and brittle, with obvious webbing on the leaves.

Some plants (e.g. hibiscus) exhibit a toxic response to TSSM feeding, with leaves yellowing and dropping from the plant even at quite low mite population densities. If infestations proceed without control measures, plants may be killed.

Mite populations seem to explode at certain times of the year, since the life cycle varies considerably with temperature. Other factors, such as humidity, plant nutrition and cultivar, are important and, at times, can be used to help reduce mite outbreaks.

Control Strategies

In ornamental crops, monitor with regular crop inspections to detect early infestations before mites build up. Pay particular attention to susceptible varieties and crops. In crops such as rose, inspect both upper and lower canopies.

For vegetable crops, conduct a proper cleanup at the end of the crop to reduce initial infestations in the following crop. Do this just before the overwintering or diapausing phase of the spider mites, since the diapausing mites hibernate in the ground, hollow stems, pipefittings, cracks and crevices during the fall and winter. The mites become active again during late winter and early spring. The red mite stages are generally pesticide resistant and are not as readily fed upon by predators. When the red diapausing mites are detected, use soap sprays on lightly infested leaves and remove and destroy more heavily infested leaves.

Biological Control

Control spider mites biologically using the predatory mite *Phytoseiulus persimilis*. Other predatory mites can be used against this pest, including some strains that are high-temperature tolerant or pesticide resistant. For example, the predatory mite *Amblyseius californicus* is reported to better tolerate dry conditions and *A. fallacis* is resistant to some pesticides. Many Ontario growers have had good success with these predators.

Phytoseiulus persimilis

Phytoseiulus persimilis is about the same size as TSSM but is pear-shaped, pale salmon to bright orange, does not have two spots and moves more rapidly on long legs. It feeds on spider mites and does not diapause.

Without spider mites, the predators die. This means new spider mite infestations require new introductions of the predator. Adult predators feed on about seven adults or 15–20 eggs per day. At 20°C, *persimilis* almost doubles the reproductive rate of the predator. Control with *P. persimilis* is best between 20°C and 26°C. Above 30°C and at humidities under 60%, predators do not thrive and seek cooler, more protected areas lower in the crop canopy. In contrast, TSSM thrive under these conditions.

Predators are available commercially either mixed with vermiculite or on bean leaves. With either carrier, treat infested plants at first sign of damage. Try to place a few predators onto every infested leaf. Before releasing the predators, ensure that they are alive and very active.

Cultural Control

Misting plants and maintaining relatively high humidities help suppress spider mite populations. For example, at 20°C and 36% RH, a female TSSM will lay about seven eggs per day; at 95% humidity, about 30% fewer eggs are laid.

Chemical Control

Because of their great reproductive potential, two-spotted spider mites easily develop pesticide resistance. To effectively manage this pest using pesticides, observe these guidelines:

- Direct sprays to the underside of leaves where spider mites usually congregate.
- Good coverage is essential to good control, particularly when using contact miticides such as Dyno-Mite and Floramite.
- The webs in areas of high mite density can protect the mites and the eggs within and beneath the web. In such cases, use higher spray pressures to penetrate the web.
- Use non-chemical control options as much as possible to minimize the development of pesticide resistance.

Aphids

Description and Life History

Aphids are small (2–3 mm), soft-bodied insects with long legs and antennae. A pair of tube-like structures called cornicles projects from the posterior end. Several species may infest greenhouses, with colour patterns ranging between black, grey, red, yellow and green. The species most commonly found in greenhouse crops are the green peach aphid *(Myzus persicae)*, the cotton or melon aphid *(Aphis gossypi)*, the foxglove aphid (*Aulacorthum solani)* and the potato aphid *(Macrosiphum euphorbiae)*.

The green peach aphid used to be the predominant aphid species in Ontario until the early 1990s, when the melon aphid started to become much more common. In the late 1990s, the incidence of potato aphid and foxglove aphid in Ontario greenhouses increased and currently the foxglove aphid is the most common aphid pest.

Adult aphids are predominantly wingless, although winged adults can develop under conditions of high population density. This adaptation serves as a dispersal mechanism, allowing aphids to move into a greenhouse from outside or to spread rapidly within a greenhouse.

In a greenhouse situation, all aphids are female and give birth to live young. These offspring can reproduce within 7–10 days. One aphid can give birth to 60–100 young over a 20-day period. Aphids can rapidly achieve very large populations.

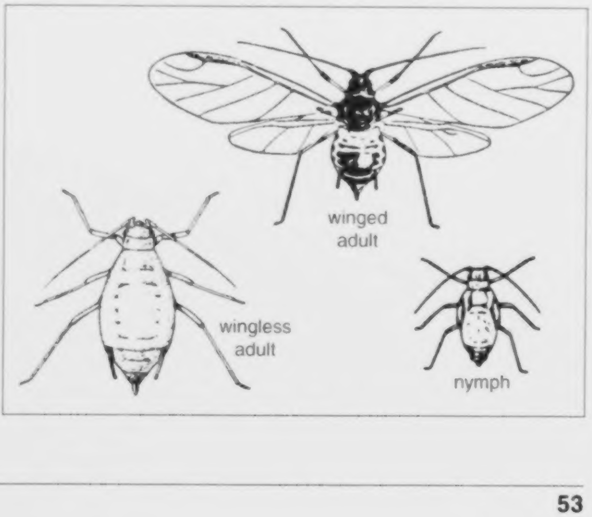
Damage

Aphids pierce plant tissue with their mouthparts and suck out the sap, causing deformed leaves and flowers. Distortion of the growing points of plants is particularly common with the foxglove aphid.

Aphids moult through a number of different stages before they become adults. The cast-off skins they leave behind each time they moult are an indicator of their presence.

They excrete a sugary, sticky substance called honeydew, which promotes the development of black, sooty mould fungus. Some aphids can transmit plant virus diseases, such as cucumber mosaic virus in cucumber crops.

FIGURE 4–5. Green Peach Aphid



Control Strategies

When monitoring for aphids, catch winged adults on yellow sticky cards.

For wingless aphids, inspect new foliage carefully and regularly to prevent large infestations.

Spot treating isolated infestations can prevent their spread to the rest of the greenhouse.

When infestations occur in the blossom stage, smokes may be more effective and less phytotoxic to plants.

Biological Control

Several types of biological control agents are readily available: the predatory midge *Aphidoletes aphidimyza*, the parasitic wasp *Aphidius* spp. and ladybeetles (*Hippodamia convergens* and *Harmonia axyridis*). *Aphidoletes* and ladybeetles are usually used to supplement the activity of *Aphidius* and for reducing aphid populations in "hot spot" areas.

Aphidoletes aphidimyza

In the adult stage, *A. aphidimyza* resemble small mosquitoes or fungus gnats. Females lay up to 200 eggs in their lifetime. Eggs are laid close to aphid colonies, so the orange larvae have a readily available food source on hatching.

Larvae usually hatch after two to three days. After 7–14 days in the larval stage, they drop to the floor to pupate. The pupal stage usually lasts about two weeks. Adult *A. aphidimyza* feed on honeydew and larvae can kill 3–50 aphids per day. Under natural day lengths, *A. aphidimyza* enters diapause between September and March; they are not effective during this period.

Aphidius spp.

This parasitic wasp does not enter diapause and is usually more effective during winter, early spring and fall. During summer, other parasitic wasp species can parasitize *Aphidius*, reducing their impact on aphid populations. Optimum conditions for *Aphidius* are 18°C–25°C and 80% RH. *Aphidius* completes its development from egg to adult in about 10 days at 25°C and 14 days at 21°C.

Several species of *Aphidius* are commercially available. *Aphidius matricariae* can parasitize about 40 aphid species, including the green peach aphid. It occurs naturally in Ontario and it is not unusual to find natural infestations in greenhouses where pesticide use has been reduced. *Aphidius colemani* is effective against both the melon aphid and the green peach aphid, but not against the foxglove or potato aphids. *Aphidius ervi* is the best choice against the foxglove and potato aphids.

Lady beetles (Harmonia axyridis and Hippodamia convergens)

Both adult and larval ladybeetles feed on aphids and can eat large numbers during the course of their lifetime. Ladybeetles enter diapause under short-day conditions. When day lengths are suitable, ladybeetles must feed on aphids to maintain egg production. Eggs are torpedo-shaped and orange. They are laid in circular clusters on the underside of leaves, and hatch in two to five days.

The larval stage lasts for about three weeks, after which they pupate. Adults emerge from pupal cases after three to five days. To increase the percentage of ladybeetles remaining in the greenhouse, sprinkle a sweet liquid (e.g., diluted pop) over the beetles and release them in late evening. The sweet liquid provides an immediate energy and water source.

Harmonia ladybeetles (also known as the multi-coloured Asian lady beetle) have become a pest in their own right in southern Ontario. Large populations have established outside resulting in them becoming a nuisance pest for homeowners, when they enter houses looking for overwintering sites. However, more importantly, they are also a pest of grapes grown for wine, with adults beetles infesting ripe grape bunches and contaminating wine production. Their establishment in the outdoor Ontario environment has nothing to do with their use a biocontrol agent in greenhouses but rather as a result of their introduction into North America from Asia many years ago. However, the poor public perception of these insects has resulted in fewer commercial insectaries producing and selling them, even though they can be very effective.

Fungus Gnats

Description and Life History

The grey to black adult fly is about 3–4 mm long with long legs, thread-like antennae and large compound eyes that meet above the base of the antennae. The adult is a weak flier, frequently observed resting on the media surface. Each female lives about 10 days and lays about 150 oval, white eggs in the organic matter of the media. Eggs hatch in two to seven days, depending on the temperature, producing white larvae that are 4–6 mm long.

The larvae have 12 abdominal segments and a distinctive shiny black head. The larvae pupate in the soil and remain immobile for four to six days, after which adult flies emerge. As with most insects, fungus gnats become more active and reproduce more quickly at warmer temperatures. The life cycle can be completed in 21 days at 24°C, compared with 38 days at 16°C.

Shoreflies, another common greenhouse pest, are often confused with fungus gnats. The adults are stouter than fungus gnats, stronger fliers and have four clear spots on the wings. Shorefly larvae live in soil, like fungus gnats but lack the distinctive black head capsule. They are likely to prefer moister conditions than fungus gnats and are often found in wet areas under benches with both adults and larvae feeding on algae.

Shoreflies are not usually a direct threat to greenhouse crops but can feed on roots in recirculating systems. Shorefly control requires controlling algae, either directly (by applying chemicals) or indirectly (by reducing moisture necessary for algal growth; or reducing the high light levels the algae need, perhaps by the use of blackout skirts around benches).

Damage

Although fungus gnats generally feed on decaying organic matter in the soil, they can also feed on the young roots of plants. This is especially true when gnat populations are high.

Fungus gnats have occasionally been observed feeding on the youngest shoots of cucumbers. Root feeding by fungus gnats makes a plant susceptible to root diseases such as *Pythium* root rot. Fungus gnats and shoreflies have also been implicated in the spread of disease-causing organisms such as *Pythium, Fusarium, Verticillium* and *Rhizoctonia*.

Control Strategies

Sanitation inside the greenhouse and in the surrounding outside area is very important.

Avoid overwatering and maintain good drainage to prevent water puddling — fungus gnats and shoreflies thrive in moist conditions.

Biological Control

Biological control agents include a predatory mite, *Hypoaspis*, a predatory beetle *Atheta coriaria* and a parasitic nematode, *Steinernema feltiae*.

FIGURE 4–6. Dark-Winged Fungus Gnats

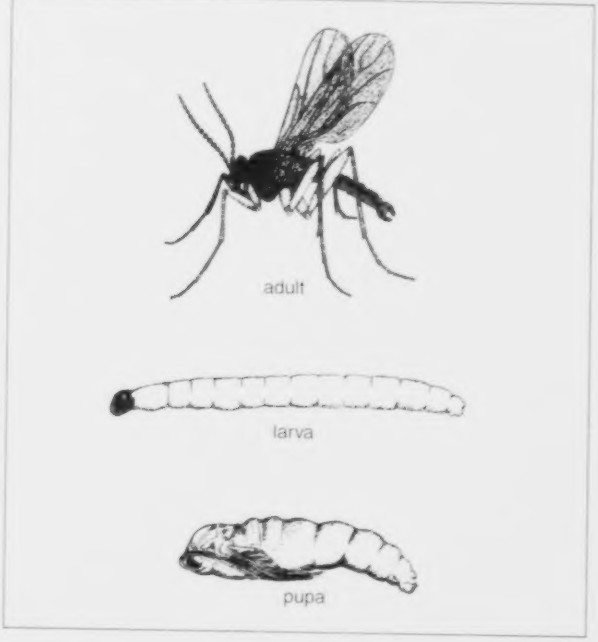
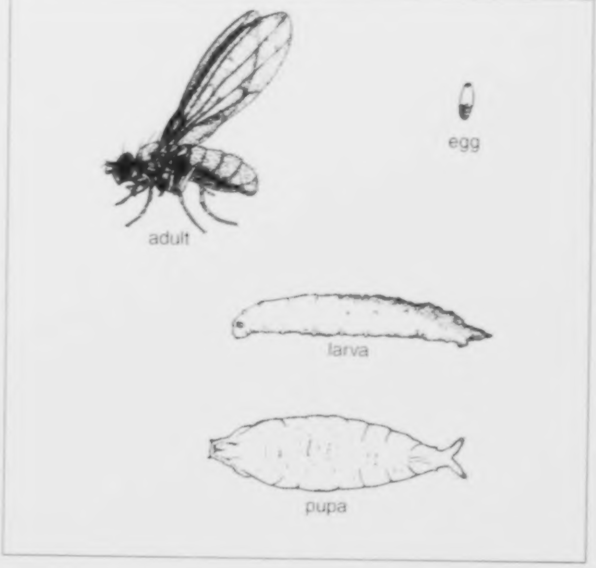


FIGURE 4–7. Shoreflies



Hypoaspis

Hypoaspis is a soil-dwelling, brown mite that feeds on fungus gnat eggs and larvae, algae, thrips pupae, springtails, nematodes, and larvae of various flies and beetles. *Hypoaspis* is a hardy mite that can live about 24 days without food. It is not affected by low light conditions and has a life cycle of about 9–11 days under greenhouse conditions.

It is found mainly in the top 1 cm or on the surface of the plant media. It works best when applied to the media just after plants are potted up or vegetable seedlings planted out. *Hypoaspis* is most effective if introduced when fungus gnat populations are still low or nonexistent.

Atheta coriaria

The rove beetle *Atheta coriaria* is a small, black soil-dwelling beetle about 3–4 mm long. It is very active and both the adult and the three larval stages feed on fungus gnats (eggs and larvae), shoreflies (eggs and larvae) and thrips (pupae). It is produced and sold commercially but is also naturally occurring and is often found in greenhouses where pesticide use is reduced. It should be used in a similar fashion to *Hypoaspis*, introduced into the crop early to control soil-dwelling pests.

Nematodes

The nematode *Steinernema feltiae* is best used under higher population conditions. Nematodes enter the body openings of fungus gnat larvae then release bacteria, which multiply and kill the larvae. Because nematodes are believed unable to multiply within the bodies of fungus gnat larvae, use several consecutive nematode applications to achieve control. Nematodes do not control shoreflies.

To use nematodes successfully:

- Shake nematode stock solutions every hour to incorporate oxygen into the water.
- Use the solution within four hours.
- Media temperatures should be 16°C–30°C.
- Never expose nematode suspensions to direct sunlight, which destroys the bacteria within the bodies of the nematodes.
- Plant media should be pH 3–8.
- Check the compatibility or residual activity of fungicides before applying to media that have been, or will be, treated with nematodes.

Chemical Control

Soil drenches can effectively control the larvae.

Leafminers

Description and Life History

Two main species of leafminers affect Ontario growers: the vegetable leafminer *(Liriomyza sativae)* and the serpentine leafminer *(Liriomyza trifolii)*. A third species, the pea leafminer, *Liriomyza huidobrensis*, which is a major pest in other parts of the world, has also been found in Ontario. Although the serpentine leafminer can complete development on tomato and cucumber, it prefers chrysanthemum, gerbera and gypsophila. Conversely, vegetable leafminer prefers tomato, cucumber and celery but will attack chrysanthemum and other plants in the absence of its preferred host. The pea leafminer has a wider host range and can move into field-grown crops as well, including vegetable crops such as cole crops, lettuce and celery. The three species of leafminer are similar in appearance and biology.

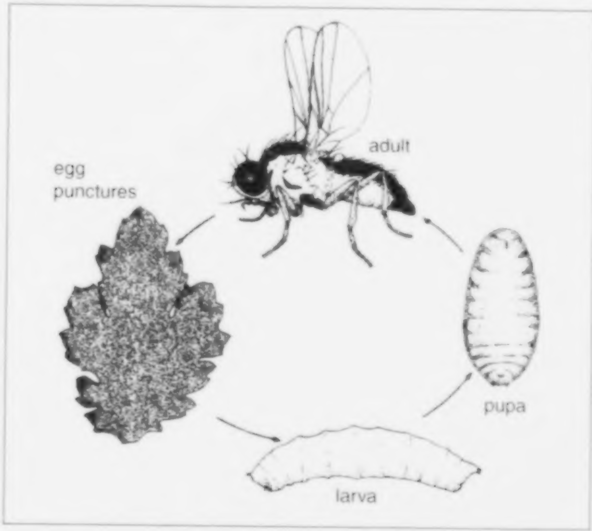
The adult leafminer is small (approximately 3 mm long), with black and yellow markings on the head and thorax. Adults become active at sunrise. Females feed on soft, succulent leaves by piercing the surface with their ovipositor, then lapping the liquid exuding from the leaf. The leaf wounds made by the female are called "stipples."

Female flies begin laying eggs 12–24 hours after emerging from the pupa. They lay about 250 eggs during their approximately 30-day lifetime. Eggs are laid in about one out of seven leaf punctures (or "stipples"). The optimal temperature for leafminer development is 30°C. At temperatures above or below 30°C, egg production/female declines considerably. After two to four days, eggs hatch and the larvae begin feeding (or mining) in the leaf tissue.

The larvae mature in four to seven days in summer, then cut a hole in the leaf surface and drop to the ground. Pupation takes place within a few hours, in the plant media or on plastic sheeting (where used). Pupation can also occur on the leaves. The pupal stage may last 5–10 days in the summer and up to 90 days during periods of low temperature (10°C–12°C) and scarce food supply. This may account for the winter survival of leaf miners around the inside perimeter of the greenhouse, though no adult leafminers are evident. From the pupae, a new generation of adult flies emerges.

There is considerable overlapping of stages of the insect life cycle within any greenhouse. The complete life cycle of the leafminer can be 14 days at 30°C, 24 days at 20°C and 65 days at 14°C.

FIGURE 4–8. Leafminer



Damage

Leafminer feeding may indirectly affect yield by reducing the plant's photosynthetic area and by damaging water-conducting vessels (causing leaf desiccation and leaf drop).

Feeding damage by leafminers mars the appearance of ornamental crops, significantly reducing their economic value.

Control Strategies

Inspect all new plant material entering the greenhouse.

Destroy infested seedlings, cuttings and plant parts or those showing evidence of stippling.

If growing in ground beds, steam-sterilize the entire greenhouse floor between crops.

Monitor the crop for pests with yellow sticky cards and regular crop inspections.

Get rid of weeds inside and outside the greenhouse. Weeds such as lamb's-quarters, chickweed, dandelion, plantain, common mallow and nightshade are good hosts for leafminers.

Don't over-fertilize the crop — excess nitrogen levels can increase leafminer problems.

Bag and remove detached leaves from the greenhouse as soon as possible. Leafminer larvae can complete their development in leaves even after they are removed from the plant.

Biological Control

Biological control agents include the parasitic wasps *Diglyphus isaea* and *Dacnusa sibirica*. *Diglyphus* is likely to be a better choice in summer, when its numbers may be supplemented by naturally occurring populations migrating into the greenhouse from outside. *Dacnusa* is reported to perform better than *Diglyphus* over the winter.

Diglyphus isaea

Diglyphus is a small, black wasp with a metallic green sheen and short antennae. After locating a mine, the female first paralyzes the leafminer then inserts an egg through the leaf, placing it near the leafminer. It may deposit up to five eggs in a mine in this manner. The larva that hatches is initially colourless then becomes yellow-brown and finally turquoise. Development time from egg to adult is about 11 days at 25°C. This is generally shorter than that of both the leafminer and *Dacnusa*.

Diglyphus can parasitize leafminers already parasitized by *Dacnusa*. It becomes the dominant species during summer, when warm conditions favour activity. Presence of short mines indicates *Diglyphus* activity, as the paralyzed leafminer stops feeding immediately. The presence of *Diglyphus* larvae can be detected by holding leafminer infested leaves up to the light and examining with a hand lens.

Dacnusa sibirica

The adult is a small, black wasp that differs from *Diglyphus* in having long, flexible antennae and lacking the metallic green sheen. Unlike *Diglyphus*, a female *Dacnusa* inserts an egg directly into the body of the leafminer. Each female lives for about 2 weeks, during which time she may lay up to 90 eggs.

Eggs hatch within 4 days, and the larvae mature within the leafminer pupae. Development time from egg to adult is about two weeks at 22°C. All *Dacnusa* development takes place within the leafminer's body; therefore, assessing parasitism is difficult.

Chemical Control

Leafminers easily develop insecticide resistance.

Ensure good pesticide coverage of the crop.

Rotate pesticide classes every two to three weeks on crops for which registered pesticides exist. Currently, pesticide registrations exist only for ornamental crops.

Line drawings of insects in this section are used with permission from *Insect and Related Pests of Flowers and Foliage Plants* (1994). North Carolina Co-operative Extension Service. Ed. J. R. Baker.

5. Occasional Pests

Ants

Ants are easily recognized by their elbowed antennae (bent in the shape of an elbow) and narrow waists. They range from 1.5–6 mm long.

Ants are attracted to sweet substances. In greenhouses where insect feeding has produced honeydew or where flowers have nectaries, ants may be a problem. Treat all ant trails or nests located in or near the greenhouse. Flooding nests with insecticidal soap and using household boric acid baits can provide some control.

Beetles

Beetles comprise the largest order of insects but very few are pests of greenhouse ornamental crops. However, two are of note.

The Japanese beetle is a quarantine insect pest, which is found in parts of Ontario. The adult beetle is about 1 cm long, brown with a metallic green sheen to it. It has a number of distinctive white tufts at the edge of its wing covers along each side of its body. The beetle larvae live in the soil and are "C"-shaped with brown heads and three pairs of legs. The mature larvae are about 2.5 cm in length. The quarantine status of this beetle means that their movement and that of infested plants, soil and related matter is regulated to help prevent further spread into uninfested areas. While not a major pest of greenhouse crops in Ontario, it can have an impact on both domestic and export movement of plant material in some situations, depending on the crops being grown and the facility in which they are grown. Some crops such as grasses and sedges are of particular concern. Contact your local CFIA office (see Appendix D, *Other Contacts*, on page 146) for more information.

The second beetle of importance is the black vine weevil (BVW). Weevils (or snout beetles) have a hard body with a snout and elbowed antennae. The BVW is dull brown to black, about 9 mm long with fine ridges along the back. The larvae are legless grubs, white with reddish-brown heads and are found among roots of various bedding plants. Adults actively lay eggs in June and the larvae feed on the roots for the rest of the season. The larvae will attack a wide range of plants including rose, geranium, fern, gardenia, kalanchoe and rhododendron. Although the adult does not fly, it can move to new plantings easily.

Use control measures in late May and June. Inspecting the roots of all material introduced to the greenhouse may prevent an infestation.

Caterpillars/Moths

Several different insects have caterpillar stages that damage greenhouse crops. One, *Duponchelia fovealis* is a pest of quarantine significance. Others include leaf rollers, armyworms, cutworms, loopers, fruitworms, hornworms and leaf tier and stalk borers. The adult moths of these caterpillars are often attracted to greenhouse lights in the summer and will then lay eggs that hatch into the caterpillar pest.

Duponchelia fovealis is a small nondescript greyish-brown moth with a wide host range that includes many greenhouse ornamental crops. It is Mediterranean in origin but has become established in greenhouse production in many northern European countries. It is not established in North America, however, it is often intercepted in produce and plant material from Europe. Occasional infestations in Canada and the USA result in quarantine action and eradication of the infestation. Host crops include, rose, begonia, cyclamen, gerbera, kalanchoe, anthurium and poinsettia. Contact your local CFIA office (see Appendix D, *Other Contacts*, on page 146) for more information.

Armyworms and cutworms feed directly on plant foliage and may cause considerable damage. Both insects are dark brown or grey with longitudinal stripes. Cutworms burrow into the soil during the day and come out to feed at night. Use insecticides recommended for caterpillars to bring armyworm and cutworm infestations under control.

Cabbage loopers commonly attack certain greenhouse crops such as alstroemeria between July and September.

Cabbage loopers are green with faint white longitudinal body stripes.

Stalk borers bore into plant stems, making them more difficult to control.

Another damaging borer, the European corn borer, can be a serious pest of greenhouse vegetables, infesting many fruits before being detected. They normally begin infestations in spring around May to early June. There are two generations of this borer in southwestern Ontario and one generation elsewhere in Ontario.

Pheromone traps can be used to detect certain moth species, and light traps can be used to monitor many species.

If you detect these pests early, begin control before the small caterpillars start feeding. Screened vents help prevent the entry of moths and a good inside/outside weed control program will reduce potential infestation sites. Apply a bacterial insecticide, Dipel or Thuricide, for good control of loopers and most leaf-eating caterpillars that are not miners.

Grasshoppers

Grasshoppers are easily recognizable and occasionally invade greenhouses. They will feed on almost any vegetation and, in large numbers, can destroy plants. Grass and weeds near greenhouses may allow a grasshopper infestation to occur, usually in late summer and fall.

Mealybugs

Two distinct groups of mealybugs are found in greenhouses. The more common foliage-feeding mealybugs are white, wax-covered, scale-like insects with piercing mouthparts that remove plant sap.

Mealybugs produce large amounts of honeydew. The females (1–3 mm long) lay large numbers of eggs in masses of wax. Active immature mealybugs called crawlers hatch from these eggs in 5–10 days. The nymphs mature into reproductive adults in six to eight weeks.

Damage is caused by the removal of plant sap, the growth of black, sooty mould fungus on the honeydew and the unsightly appearance of the waxy secretions.

Mealybugs are a serious greenhouse pest because the crawlers spread rapidly and exist under bud scales and within leaf axils. Males, present in low numbers, are small, winged insects.

Occasionally, root-feeding or subterranean mealybugs are found, within masses of wax, on the roots of wilting or yellowing plants. These insects are much like those described above but secrete less wax over their bodies.

Inspect all plant materials entering the greenhouse carefully for the presence of mealybugs. The crawler stage of all mealybugs may spread to other plants through contaminated equipment or via water leaching through pots. Most infestations result from introduced contaminated material.

Biological control agents for this pest include the Australian ladybeetle, *Cryptolaemus montrouzieri*, the common ladybeetle, *Hippodamia convergens*, and a parasitic wasp, *Leptomastix dactylopii*.

Midges

These small (1 mm), delicate flies lay eggs in the stems, leaves or flower buds of ornamental plants. The larvae burrow into plant tissue, causing swellings of stems, galls on leaves or collapse of buds.

The Swede midge is a quarantineable pest that affects Brassica crops. It is primarily a pest of field vegetables, however Brassica bedding plants (cabbages, broccoli, etc.) and ornamental cabbages and kale are also affected. Swede midge is present in parts of Ontario and Quebec. The CFIA has a Swede midge Certification Program (SMCP) in place to regulate the movement of host transplants and soil associated with the transplants from infested areas to uninfested areas (either within Canada or the USA). If host plants are not grown in a greenhouse certified under the SMCP, Brassica plants cannot be shipped out of these areas into uninfested regions. This obviously has a large impact on those growers who export these types of products. In order to meet all the requirements set out in the SMCP, greenhouse flower growers may not find it to be economically feasible. Contact your local CFIA office (see Appendix D, *Other Contacts*, on page 146) for more information.

The rose midge is a concern to Ontario rose growers as it can quickly cause serious losses. Flower buds bend or become distorted, then turn brown and die. The rose midge is most abundant during the hot summer months, when it enters greenhouses from infestations on outdoor roses. Eggs hatch in approximately two days; larvae mature in five to seven days and drop to the soil to pupate in another five to six days. The adult midge then emerges and lives for only a couple of days. Pesticide sprays for the adult stage are ineffective. For rose midge, use a foliar spray of the systemic Orthene to control larvae in the base of the buds.

Mites

Cyclamen Mite/Broad Mite

Cyclamen mites and broad mites are microscopic in size. They are no more than 0.25 mm long and cannot be seen without magnification. The hind pair of legs of the female is thread-like while those of the male are pincer-like.

The pale brown female mite deposits approximately 100 eggs, 80% of them female, around the crown of the plant or along the midrib of unfolded leaves. The mites develop through the six-legged larval stage and quiescent nymphal stage with eight legs, similarly to the two-spotted mite. The life cycle from egg to adult is about two weeks but varies depending on the temperature.

Distorted leaf tissue and/or small, blasted or twisted flower buds and flowers are usually the first damage symptoms. Foliage will often show purplish areas. The cyclamen mites feed around the crowns of plants or in the flower buds. Cyclamen is usually the most seriously injured, but many foliage and bedding plants, as well as other potted crops, can also be attacked.

Tomato Russet Mites

The adult mite is 0.2 mm long and 0.05 mm wide. Because of its small size, the mite is not noticed on plants until it reaches damaging levels. At this time, the stems, leaves and fruit appear beige or bronze as a result of the high mite population density.

Russet mites appear to thrive under dry conditions. The life cycle lasts about six days at 27°C and 30% RH. Females can lay about 16 eggs during their lifetime of about three weeks. Russet mites feed first on stems, then on leaves.

Damage symptoms include yellowing, curling, and wilting of leaves; flower abortion; and bronzed, cracked fruit. If not controlled, the tomato russet mite will eventually kill the plant.

Alternative hosts for this pest include nightshade, petunia and several other species of the tomato family.

No early detection techniques exist for this mite. Once established in a crop, they easily spread by hands, equipment and clothing.

There are no current recommendations for biological control. Work to date indicates that two predatory mites, *Amblyseius fallacis* and *Typhlodromus occidentalis*, are potential biocontrol agents.

Scale Insects

Scales are minute, wingless insects up to 3 mm long. They have piercing/sucking mouthparts and an oval or hemispherical body shape. Scales secrete a characteristic waxy or scale-like covering over their bodies. Males, which are rare, have wings.

Most scales are females that lay hundreds of eggs under their immobile scale. When these eggs hatch, the small crawlers migrate to new feeding sites. Damage is caused by the removal of sap from plants, which results in yellowing, wilting, stunting and distortion of plants.

Several species have been identified on greenhouse ornamentals in recent years, mainly due to the increased amount of foliar stock being imported from tropical areas. Many newer introductions of fern, palm and ivy plants are susceptible to scale infestations.

To help control scale, quarantine, check and treat or destroy infested material.

Biological control agents for soft and armoured scales include two small ladybeetles, *Chilocorus nigritus* and *Lindorus lophanthae*. A small parasitic wasp, *Metaphycus helvolus*, has been reported to help manage several species of soft scales. Another wasp, *Aphytis melinus*, can be used for several species of armoured scales.

Ivy Scale and Greedy Scale

These scales are similar in appearance, pale and circular with a prominent yellowish nipple in the centre. Both attack a wide variety of greenhouse plants such as ivy, palm, ficus and fuchsia.

Fern Scale

The shield of this scale resembles an oyster shell. It is brown with a lighter terminal nipple and is usually found on ferns and other foliage.

Brown Soft Scale

Female scales are flat, brown and pliable. They have a wide host range and produce large amounts of honeydew that promotes the development of black, sooty mould fungus.

Hemispherical Scale

The scale covering on this species is very convex, brown and shiny. Ferns are a favourite host.

Slugs and Snails

Slugs are dark grey, soft-bodied creatures, 1.3–10 cm long. They glide over plants leaving a shiny trail. Slugs eat the foliage of most greenhouse plants, shredding the leaves and they may completely destroy a plant.

Snails are similar in colour and appearance to slugs, except that a snail bears a noticeable shell. The shell varies in colour and markings, and may be 1.3–5 cm in diameter. Snails are particularly injurious to seedlings. They eat holes in the flowers and leaves of many plants, leaving them shiny and tattered.

Individual snails may lay up to 100 eggs, depending on the species. Slugs lay fewer eggs that may remain unhatched for long periods under dry conditions. They hatch upon return of moist conditions.

Both slugs and snails need a damp environment and fairly humid air to survive. They avoid the sun and come out primarily at night or on cloudy days. During the day, slugs hide under boards and rocks or in other damp, shady places. If the air or substrate is dry, a snail can pull its entire body into its shell and remain dormant for up to four years.

Indirect control strategies for these organisms should focus on reducing their favoured habitat.

Remove boards, bricks, etc. that are in contact with the ground or arrange these to permit proper air circulation around and under them.

Maintain a plant density that permits sunshine to penetrate to the ground level, provides good air circulation and allows the plant media to dry.

Where a low plant density is inappropriate, use a ground cover unattractive to snails (e.g., rough-cut cedar chips or crushed eggshells). Sawdust and diatomaceous earth are effective barriers if kept dry.

Various devices can trap or attract slugs and snails for subsequent destruction. Use traps using beer or a mixture of water and commercial yeast as an attractant. Invert flowerpots and fill with crushed snails or slugs, or invert grapefruit halves to attract slugs and snails.

Chemical controls involve pesticides formulated as baits. Metaldehyde is toxic and must be inaccessible to children and pets. Prolonged use of baits is likely to produce a local bait-resistant population.

Sowbugs/Pillbugs

Sowbugs and pillbugs have grey, flattened, oval bodies up to 13 mm long with seven pairs of legs. Sowbugs have two small, tail-like structures that the pillbugs lack.

They are both small decomposers but occasionally feed on roots and tender plant parts, causing seedling damage. They feed at night and hide during the day, preferring dark, moist areas with abundant organic matter.

Sterilizing soil and eliminating decaying plant material and moist areas will help prevent a buildup of these pests. Many strategies used for snail and slug control also suppress sowbug/pillbug populations.

Springtails

Springtails are tiny, wingless insects 2–6 mm long. They range in colour from white, grey or yellow, to red, orange, purple, brown or mottled hues.

They are usually found on the surface of moist soil, in pots or within the soil and have a spring-like apparatus at the end of the abdomen that allows them to spring into the air.

Most springtails are scavengers, feeding on decaying organic matter, algae or fungi. Because they usually don't feed on living plant material, chemical controls are rarely necessary.

Striped Cucumber Beetle

Striped cucumber beetles are yellow-green beetles about 6 mm long. They have three longitudinal stripes. These beetles and a relative, the spotted cucumber beetle, carry the bacteria *Erwinia tracheiphila,* which causes bacterial wilt in cucumbers and related species such as melons and squash.

Striped adult cucumber beetles overwinter outdoors under old leaves, old logs or garbage. They emerge the following spring, mate, feed for several weeks, then lay orange-yellow eggs in the soil at the base of plants.

Larvae usually hatch in 10 days, then feed on the roots of plants for two to six weeks. Fully grown larvae are about

9 mm long. Pupation takes place in the soil and adults emerge after about one week. There is only one generation per year in Ontario.

The adult beetles damage plants by chewing on leaves, stems and fruits but the greatest damage comes from the wilt-causing bacteria they often carry, which can survive the winter in their gut. In the spring, the beetles inoculate plants with the disease as they feed on the plant tissue.

There is no control for the wilt once a plant is infected. Inoculated leaves generally wilt within five to six days, and the plant dies within two weeks. Striped cucumber beetles can also transmit cucumber mosaic virus.

The best control comes from insect barriers installed over all greenhouse openings to exclude the adult beetles.

Symphylans

Symphylans are found under stones, in rotting wood and in moist soil high in decaying organic matter. They are small white creatures resembling centipedes, with slender, long, white bodies (1–5 mm long), 10–12 pairs of legs and long antennae. Centipedes have 15 pairs of legs.

While centipedes are beneficial predators that prey on many insects, symphylans can feed on the roots of plants. On many crops, damage shows as tiny black marks on the roots where a hemispherical piece of tissue has been scooped out. Injured roots become stubby and the plant becomes stunted. Damage caused by symphylans to roots and root hairs provides entry points for root-rotting diseases.

Steam sterilization of soil or heating of soil by solarization can help to reduce populations.

Tarnished Plant Bug

These bugs are about 6 mm long, yellow-brown, with piercing mouthparts. The adults and their green nymphs feed on many crop and weed species. They can be serious pests to greenhouse crops such as chrysanthemum, gerbera, cucumber and pepper.

Eggs are inserted into plant tissue and the small nymphs complete their life cycle in about four weeks. They damage new growth by causing foliage distortion and dead or distorted flower buds. They are most active during the summer and fall, and may gain access to the greenhouses from surrounding weedy areas.

Tarnished plant bugs tend to appear in crops where pesticide use is minimal. Eliminating weeds that may serve as spring/summer hosts or overwintering sites will lower overall populations. Screening vents will help control this pest.

Tomato Pinworm

The tomato pinworm (TPW) is a semi-tropical pest that can infest tomato crops in Ontario. It inflicts damage by feeding on tomato leaves and fruit. Other suitable hosts for TPW are potatoes and eggplant. Weeds such as nightshade and its relatives may also serve as hosts.

The adult is a small, light-brown moth about 6 mm long. It is generally more active at night, laying most of its eggs on younger leaves during the first few nights of activity. Newly hatched larvae walk on the leaf surface for a very short time before entering the leaf to start mining.

There are four larval stages, the first two spent in the leaf. The third and fourth stages may be found between two leaves knitted together, in a leaf that has been folded over or inside fruits. Larvae characteristically enter fruits just beneath the calyx.

Mature larvae may either remain on the plant or drop to the ground to pupate. On the ground, pupation usually occurs within the top 15 cm of soil. Tomato pinworms do not diapause. Their development continues year-round, slowing during cold weather periods. Development time from egg to adult usually ranges between 28 and 70 days, depending on temperature. The life cycle is completed in 28 days at 24°C, and can be as short as 19 days at 30°C.

For control:

- Inspect all seedlings for larval feeding damage.
- Destroy all old infested plants and any debris from infested crops.
- Monitor for the presence of tomato pinworm with pheromone or light traps and by inspecting crops regularly. Note that pheromone traps attract only male tomato pinworm, whereas light traps attract both sexes of tomato pinworm and many other insect species.
- Hand-pick damaged leaves and destroy larvae within the mines.
- Destroy weeds and stray tomato seedlings inside and around the greenhouse.
- Install insect barriers over vents.

Vertebrate Pests

Rats and mice may be very destructive in the greenhouse. They feed on almost any food source and can cause damage by gnawing and burrowing.

Norway rats and field mice are the most common vertebrate inhabitants of greenhouses. Baits containing rodenticides such as chlorophacinone, diphacinone, warfarin and zinc phosphide can give some control. The first three chemicals are anticoagulants and multiple doses are usually required. Zinc phosphide is not an anticoagulant and is more acutely toxic — a single dose can kill. Ensure that the toxic baits are placed in covered stations where pets and children cannot get them.

To minimize the development of rodenticide resistance, particularly to the anticoagulants, always adopt other control measures, such as:

- Store all potential food material in tight-fitting containers.
- Use many traps where there are signs of activity, placing one trap every 2–3 m along walls.
- Set traps at right angles to the wall, with the bait and trigger facing the wall.
- Handle traps with gloves to avoid contaminating them with human smells.
- Try different baits. Suggested baits include peanut butter mixed with oats, raisins, gumdrops, any other sticky food material and cotton, which provides nesting material.
- Maintain several female cats, which tend to be more predacious than males, as biological control agents.

Root Nematodes

Plant parasitic nematodes are small (<1 mm long) worm-like organisms that live in the root media. They are broadly divided into two groups—ectoparasites, which attack plants externally and endoparasites, which spend at least part of their life cycle within the plant tissue.

All parasitic nematodes have stylets through which they inject saliva into plant tissue. The saliva causes most of the damage, causing necrosis or the proliferation of giant cells that produce galls.

Nematodes cause damage mainly by reducing the ability of plants to absorb water and nutrients. Aboveground symptoms of nematode damage include weakened plants that wilt in the sun, yellow or pale green leaves and stunted fruit or flowers.

Where nematicides are used between crops, nematode infestations often recur because of insufficient penetration of the chemicals into the lower soil levels. Soils so treated should always be properly aerated to avoid subsequent plant damage.

Root-Lesion Nematode, *Pratylenchus penetrans* (Cobb)

This endoparasitic nematode is native to Ontario soils and can attack many floral and vegetable crops. All stages are thread-like and invisible to the naked eye.

This nematode invades the outer layers of young roots, causing small brown-to-black elliptical lesions that merge to discolour the roots and kill them.

Northern Root-Knot Nematode, *Meloidogyne hapla* (Chitwood)

This is another endoparasitic nematode native to Ontario soils. It attacks almost all types of vegetable crops and many floral crops, particularly rose, African violet and geranium. Early larval stages are thread-like and invisible, while later stages and adults are peanut- to pearl-shaped and just visible when dissected from roots.

This nematode invades roots and settles down to cause swellings, knots or galls and excessive root proliferation. Infested roots do not necessarily become discoloured unless attacked by bacteria and fungi.

Dagger Nematode, *Xiphinema diversicaudatum* (Micoletzky)

This ectoparasitic nematode is not native to Ontario and was introduced into greenhouses on plant stocks. Dagger nematodes prefer plants with woody roots and are more frequently associated with crops such as strawberry, grape and rose. The nematode survives in the root crotches of the understock.

One of the largest nematodes attacking plants, this 6 mm, thread-like roundworm can, with care, be seen on the roots. It feeds on young roots from the soil, which causes galls similar to root-knot galls but somewhat larger. These galls are actually curved swellings in the root tip area, accentuated with the necrosis and shriveling of roots above the galls.

Pin Nematode, *Paratylenchus projectus* (Jenkins)

This nematode is native to Ontario and can attack many floral and vegetable greenhouse crops, especially rose. All stages of pin nematode are thread-like and invisible to the naked eye. This species is active in both fine-textured (clay) and coarse-textured (sandy) soils.

The pin nematode does not enter roots but feeds at root tips by probing root hairs and surface cells. No specific root symptoms, such as galls or lesions, appear. Plants infested with this nematode show general above ground symptoms.

Southern Root-Knot Nematode, *Meloidogyne incognita* (Kofoid and White)

This endoparasitic nematode is not native to Ontario but has become persistent in the protected greenhouse environment. It cannot survive outdoors during winter. It is a problem on tomato and cucumber but can also attack several floral and foliage crops.

Root damage and symptoms differ from those of the northern root-knot nematode. Plants damaged by the southern root-knot nematode have larger galls and lack fine root growths from the galls. Tomato leaves may show phosphorus deficiency (purpling) on the underside or downward curling of leaf edges; affected tomato or cucumber plants wilt readily.

Foliar Nematodes

A few nematodes attack plant foliage. Symptoms caused by leaf-feeding nematodes are similar to those of several diseases and nutrient deficiencies.

Strawberry Bud Nematode, *Aphelenchoides fragariae* (Ritzema Bos)

This nematode is not native to Ontario but was introduced on plant stock. It is primarily a problem on begonia but can attack other greenhouse ornamentals. Invisible and thread-like, it moves in moisture films on stems and leaves.

The nematode enters leaves through the stomata and feeds in the inner layers of the leaf, causing small brown spots with water-soaked margins on the underside of leaves. The spots subsequently enlarge and merge, turn dark brown and become visible on the upper surface. Finally, the entire leaf is affected.

Chrysanthemum Nematode, *Aphelenchoides ritzemabosi* (Shwartz)

This nematode is not native to Ontario but was introduced on plant stock. It is almost identical to the strawberry bud nematode and moves and infests plants in the same manner.

Early symptoms include dark-brown spots on the underside of leaves and vein discolouration. Infested leaves eventually turn brown or black, forming distinct wedge-shaped areas between the veins. Finally, the leaves dry, shrivel and hang down along the stems.

The following are cultural control measures for minimizing nematode problems:

- Use soil-free media or steam-sterilized media.
- Ensure that transplants are vigorous and free of root galls or lesions.
- Use nematode-resistant or nematode-tolerant cultivars or use nematode-resistant rootstocks where applicable.
- In soil-grown vegetable crops (e.g., tomato and cucumber), mound peat or sterile soil at the plant bases to stimulate adventitious root growth and help extend the productive life of the plants.

6. Integrated Disease Management

Integrated disease management (IDM) is a disease control philosophy that uses all available management strategies to maintain disease pressures below an economic injury threshold. It does not advocate a routine fungicide application program to prevent disease but promotes the integration of cultural, physical, biological and chemical control strategies. The routine application of fungicides for insurance purposes is no longer appropriate because it does not focus the appropriate attention on the real problem and can lead to fungicide resistance and potential environmental issues.

The basic objectives of any integrated disease management program should be to achieve at least the following:

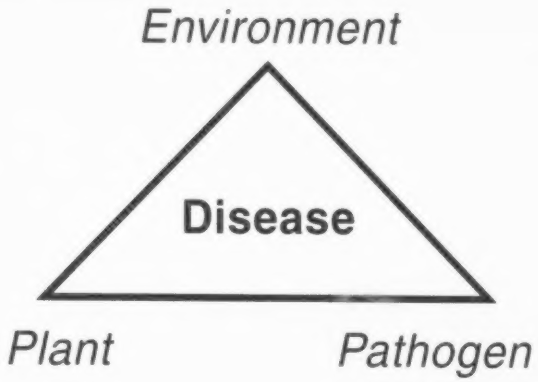
- Reduce the possibility of introducing diseases into the crop.
- Avoid creating conditions suitable for disease establishment and spread.

A sound disease management program integrates a few universal principles and concepts into the overall production system for that particular crop. It is important to understand the concepts of disease control and the strategies developed from them, to make modifications appropriate for a particular greenhouse or crop situation. A disease control program involves more than a fungicide application, which too often addresses the symptoms but not the problem.

The Disease-Triangle Concept

Three factors are necessary for disease development:

- a pathogen or disease-causing organism (e.g., a fungus or a bacterium)
- a susceptible plant for the pathogen to infect
- a suitable environment in which the first two will interact



For example, *Thielaviopsis basicola* will attack the bedding plant Vinca when air and media temperatures are cool (15°C–17°C) but rarely at temperatures above 21–22°C. However, this disease pathogen will attack pansy when temperatures are above 25–26°C, the media pH is high (above 6.5) and the sanitation is generally poor.

The plant environment includes the soil or growing media in which the roots grow and the above-ground environment or air where the shoots, leaves and flowers are produced.

Soil or media environment characteristics that must be considered include:

- pH
- nutrient levels and their balance
- EC
- moisture-holding capacity
- media texture to allow good drainage
- oxygen content

Aerial environment characteristics that must be considered include:

- light levels
- temperature
- air movement
- relative humidity
- air quality

Six General Principles of Plant Disease Control

Exclusion

The prevention of pathogens from becoming established in the greenhouse is a primary aspect of disease control. For example, geranium propagators use this principle each year when they purchase new virus-indexed/pathogen-free cuttings for stock plant production. This minimizes the potential for fungal and bacterial infections such as geranium rust or bacterial wilt.

Growers who use soil or compost in their media pasteurize the material to eliminate soil-borne pathogens. The use of new, clean pots, cell packs and flats prevents any potential carryover disease inoculum from infecting newly planted crops.

Avoidance

This involves using common-sense practices to avoid situations that promote disease development. For example, do not use overhead watering late in the day in crops with a dense canopy because this creates conditions favourable for the development of *Botrytis.*

Resistance

This involves the inherent ability of a host plant to remain healthy or resist attack, even though a pathogen is present and/or the environment is conducive to pathogen development. For example, most new tomato cultivars are being developed with genetic resistance to *Fusarium* crown and root rot; and many Rieger begonia cultivars are being bred with resistance or tolerance to powdery mildew.

Protection/Prevention

Fungicides can be applied before any disease is observed as a preventive measure to protect crops during periods when conditions are conducive to disease development. However this pro-active approach should be taken judiciously and only under specific crop conditions or crop staging. For example, application of a fungicide such as Decree at the end of the poinsettia crop can protect the bracts from *Botrytis* infections. This may be appropriate when outdoor conditions are cool and wet and the temperatures within the greenhouse have been lowered to tone the crop prior to shipping.

Application of a fungicide for *Pythium* root rot control in Easter Lilies just after visible bud is a good example of a preventive application because it is well documented that during the phase of rapid bud expansion, root rot typically sets in, resulting in lower leaf yellowing.

Eradication

Plant pathogens can be eliminated via several means, such as steam pasteurization of ground beds or rock-wool slabs, to eliminate root-borne diseases and nematodes. Sanitizing products such as chlorine bleach or quaternary ammonium chloride compounds can effectively control bacteria or fungal spores in dust or on surfaces of benches, in or on irrigation lines and emitters, and on tools used for propagation or production.

Plant breeders and primary propagators routinely index and tissue-culture vegetatively propagated plants to eliminate potential plant-infecting bacteria and viruses.

Therapy

Treat infected plants to prevent further sporulation and spread of the fungus. For example, Nova is sprayed on rose foliage to kill the mycelium of the powdery mildew fungus.

Basic Integrated Disease Control Strategies

Symptom Recognition

Successful disease management begins prior to the start of each crop. Knowing the diseases most likely to infect the crop is helpful in anticipating the potential problems that may arise. However, with so many new plant introductions each year, the susceptibility of these plants to disease is not known. Experience has shown that most new plant material is susceptible to many of the same diseases that have frustrated growers for decades.

Becoming familiar with the typical symptoms of the most common economically important diseases is important in quickly recognizing and identifying a disease when a problem appears.

Monitoring

Regular crop monitoring provides reliable information to guide an integrated disease management program if the crop inspection is routine and structured. It is essential to consider monitoring for the presence of plant diseases just as it is in reviewing crops for PGR application or for irrigation. It must be considered part of the production process. When growing a range of crops, time can be saved by concentrating on known susceptible crops or areas within the greenhouse that are known to be typical locations where certain problems arise; for example, powdery mildew near door entrances. Keep weekly records.

To monitor effectively for disease incidence and development, inspect foliage and flowers (if present) weekly. Roots should also be checked weekly, which although practical for potted crops is not for soil-grown cut flowers. Check EC (electrical conductivity) and pH biweekly for each crop grown as these two factors usually predispose plant roots to attack by various root rot pathogens. Detecting diseases early makes control easier and may mean containing a problem with only a spot spray or other localized action.

Monitoring can only be successful when the following pertinent information is recorded. This is beneficial when attempting to identify a crop problem or when completing a post crop production review. The following information should be recorded when monitoring or applying a fungicide:

- date
- compartment or section in the greenhouse
- crop species and cultivar
- stage of crop development
- diseases present or suspected
- control action (pesticide used, rate, area treated, time taken, etc.)
- environmental conditions (temperature, RH, outside weather)

Environmental Control and Manipulation

Environmental factors such as light, air temperature, plant temperature, relative humidity, air circulation, media composition, pH, and EC plus the nutritional status of the crop, not only impact on plant health but the diseases that attack them. The use of environmental controls to manage diseases is complex because of the simultaneous effect on crop production.

Know and understand the conditions required for the optimal growth of the crop and for the common diseases of that crop:

- Avoid extremes or, more importantly, rapid changes in relative humidity. This minimizes the time period and conditions suitable for *Botrytis* or powdery/downy mildew to develop.
- Be aware that temperatures of leaf surfaces are lower in plastic houses than in glass houses because of greater heat loss due to far-red radiation.
- Avoid poor air circulation within the greenhouse. This can cause uneven temperatures throughout the crop. It can also lead to free moisture forming on the plants, particularly at night, which creates ideal conditions for mildew and *Botrytis* infections.
- Avoid all extremes, as much as possible, for the crops. For example, the combination of high temperature and over-fertilization promotes *Fusarium* crown and root rot in cyclamen, while the combination of high temperature and high relative humidity is favourable to *Rhizoctonia* attacking cuttings during or just after propagation. Also avoid low temperatures to prevent outbreaks of *Pythium* in warm-temperature crops.

Modification of Cultural Practices

Chronically stressing plants makes them more susceptible to attack by disease pathogens. Plants are stressed when the root and/or shoot environments are neglected.

Understand the growing requirements of the crops being produced. Not all crops will tolerate the same conditions. For example, Easter lily and primula require very different root management; lily roots cannot tolerate being overly wet and starved for oxygen while primula cannot tolerate having the media drying out.

Monitor the media or substrate pH and EC every week if necessary. Avoid fertilization when soluble salts are high. The definition of "high salts" varies with the crop and its stage of development (see Chapter 2, *Crop Nutrition*, on page 15). High salts damage root hairs and young roots. These wound sites become entry points for disease pathogens like *Pythium* and *Fusarium*.

Use clean containers and porous, well-draining media to minimize the potential for pathogens such as *Pythium* and *Phytophthora*.

If foliar diseases are an ongoing problem, review temperature, relative humidity, air circulation patterns and watering practices. Often, by maintaining higher night temperatures, higher minimum overhead pipe temperatures or ensuring that air exchange occurs regularly throughout the night, the incidence of foliar diseases can be lessened.

Sanitation and Roguing

Sanitation is the first step in any disease management program. If a source of infection or infestation is constantly present due to poor hygiene, disease management programs will be expensive and frustrating. Carry out good sanitation practices as the first line of defence in the greenhouse, outdoors in the immediate vicinity of the greenhouse and during every stage of crop production.

Proper greenhouse sanitation is a continual, year-round process. Cleanliness on its own may not totally control pest problems but it is a basic component of any control program. It is important to:

- Use footbaths between different greenhouse compartments, particularly between propagation or stock plant areas. Routine maintenance of these footbaths is essential. Follow the label of the product being used. Household bleach is not recommended for this purpose.

- Remove dead and dying plants, leaves and flowers as detected. In geraniums, removing and disposing of all flowers away from the greenhouse plays a significant role in reducing the incidence of *Botrytis*. Do not leave diseased plants under benches.

- Place rogued plants with difficult to control diseases in commercial garbage containers and dispose of them in a landfill to reduce potential sources of inoculum.

- Dedicate wheelbarrows or soil carts used to discard diseased material strictly for disposal purposes. If this is not possible, disinfect after every use.

- Have employees wear disposable gloves when handling diseased plant material. Otherwise, employees should wash their hands thoroughly with soap or bactericidal hand lotion before performing another function. They should also wash their hands between cultivars when taking cuttings.

- Store normal crop residues well away and downwind from the greenhouse to prevent particles of media or plant tissue from being blown or sucked into the greenhouse. Preferably cover plant residues or, alternatively, move residues off-site on a routine basis.

- Keep walks and the surfaces of benches clean. Sanitize between crops.

- Carefully check both the foliage and roots for disease when bringing new vegetative cuttings into the greenhouse for stock plant production. It is advisable to isolate new plant material initially.

- Avoid over-wintering garden or houseplants in the greenhouse. They may act as the source of disease.

- Maintain good drainage to eliminate puddles and wet surfaces, as these provide ideal breeding sites for fungus gnats and shoreflies. These insect pests are a possible source of infection for root diseases such as *Pythium* and *Fusarium*.

- Keep the greenhouse free of weeds that may harbour diseases like impatiens necrotic spot virus/tomato spotted wilt virus (INSV/TSWV) or insects that can be vectors of disease.

- For soil-grown crops steam soil before planting winter crops to minimize the carryover of root and crown rot pathogens. See heading on *Soil Pasteurization* below on page 71.

- Steam traditional propagating benches regularly.

- Disinfect propagating benches and trays before propagating and between each round of rooting to eliminate bacteria and fungi.

- Use expanded metal benches rather than wooden benches for easy cleaning and to minimize the spread and survival of pathogens during propagation.

- Sweep or vacuum bench surfaces before sanitizing to ensure the best possible efficacy of sanitizer. Peat and other organic matter left on the bench prior to sanitizing reduce the efficacy of most sanitizing agents. If necessary wash down benches and walls with horticultural detergents to remove algae before sanitizing.

- Empty and sanitize tanks used to hold recirculated nutrient solution at the same time as concrete floors or troughs to prevent recontamination of the production areas.

- Dip cutting knives in 70% alcohol between cultivars to prevent the spread of disease. Between crops, perform a general disinfection of the greenhouse structure (walls), heating pipes, walks, benches or equipment. For some production systems this is not always possible.

Biosecurity

Biosecurity is the protection of Canada's economy and environment from pests and diseases. It includes reducing the risk of the introduction of new pests and diseases and eradicating or effectively managing the spread of those that have already arrived. As a producer, taking common-sense precautions to prevent pests and diseases from entering the farm is a worthwhile investment. In the context of greenhouse floriculture, this should entail good sanitation and the other integrated disease strategies described in this chapter and for pests in Chapter 3, *Integrated Pest Management*, on page 35. The development of a biosecurity policy for visitors entering the facility also plays an important role in reducing the potential for the introduction and establishment of new pests and diseases.

Disinfectants

These products provide an important role in the prevention and control of fungal and viral pathogens within the greenhouse. There are a number of products available:

- *Agribrom* can be used to control microbial slimes in greenhouse evaporative cooling systems and to control algae and microbial slimes in irrigation systems. Maintenance of desired levels in automatic irrigation systems even when using a brominator has proven difficult for most growers.
  - A 0.5–1% final solution of sodium hypochlorite bleach. Mix 1 part common household bleach with 10 parts water to obtain a final solution of 0.5%. For a 1% solution, mix 1 part bleach to 5 parts water. Use a higher strength solution (up to 1%) in cases of serious disease outbreaks or when disinfecting wooden benches. Chlorine is very effective but rapidly volatilizes when mixed in water with the strength reduced by 50% in two hours. Chlorine fumes can be harmful to plants so if plants are present in adjacent areas, ensure adequate ventilation. Organic matter very quickly inactivates the chlorine. Be aware that residual chlorine can be released from surfaces when rewetted if rapid drying has occurred.
- *Horti-Klor* is a chlorinated cleaner or detergent that can be used initially to remove algae and plant residue from packing equipment. Follow manufacturer's directions.
- *Chemprocide* is a quaternary ammonium chloride compound with broad fungicidal and bactericidal activity recommended for general surface disinfection and for foot baths.
- *Floralife D.C.D.* is a quaternary ammonium chloride compound with fungicidal and bactericidal activity. Surfaces should be pre-cleaned prior to disinfection. Surfaces should remain wet for 10 minutes.
- *Virkon* is potassium monopersulphate, a disinfectant with broad fungicidal, bactericidal and virucidal activity.
- Quaternary ammonium chloride compounds are quite stable because the chlorine is not volatile but they disinfect in a way similar to chlorine bleach. As with bleach, contact with any type of organic matter will inactivate the disinfectant. Thus, it is very important to remove as much organic matter as possible prior to application.

Soil Pasteurization Methods

Greenhouse media containing field soil and cut flower soil-based ground beds typically contain weed seeds, insects, bacteria and fungi that may be harmful to the plants being grown. This includes potting mixes and their components, unless guaranteed sterile or pasteurized by the manufacturer. Pasteurization of media containing soil is important to eliminate these harmful organisms. Ideally, this is accomplished without injuring beneficial soil organisms.

Few growers continue to use soil as an amendment to their growing media because of the difficulty in sourcing quality top soil, concerns with regard to herbicide residues, the cost of steaming and the associated labour costs.

Soilless media is not sterile but few diseases are typically present because of the low pH of the sphagnum peat being harvested from the peat bogs.

Steam

Steam is the most common heat source for pasteurization. There are different ways of handling steam, depending on the type of crop being grown. When pasteurizing soil in bulk for vegetable seedlings or potted plants, some growers find it efficient to inject steam into the bottom of a modified soil wagon or similar enclosed vehicle. After cooling, move the pasteurized soil to the area in which it will be used or store covered in an isolated area where the possibility of contamination is minimized.

Growers of cut flower or vegetable crops should follow one of two techniques when steaming soil in ground beds:

- Ground beds are initially rototilled and then covered with a tarpaulin. Steam is injected directly under the tarpaulin through either a canvas hose or a perforated, flexible plastic field tile to ensure even distribution. Soil should be of fine tilth and moist to allow rapid, uniform penetration of the steam. Many growers use a small fan to assist in raising the tarpaulin more quickly. A soil thermometer should be inserted into the soil to at least 15 cm depth to monitor temperature. Check table below to see time requirements to kill organisms upon reaching specified temperature.

- It is important that if rototilling after steaming that the rototiller is sanitized and that the soil is not tilled more deeply than the steaming temperature penetrated.

If re-using rockwool, note that steaming time depends on the wetness of the rockwool and the steam temperature. Steaming at 90°C for 30 minutes should be adequate. Generally, the wetter the rockwool, the longer the steaming period required. For this reason, the substrate should be as dry as possible before steaming. Rockwool stacked on pallets without polyethylene bags can be steam-sterilized in two hours. Rockwool wrapped in polyethylene requires five hours of steaming. Rockwool should not be stacked higher than 1.5 m. To stabilize the stacked slabs, place each row at right angles to the previous one. In addition, leave a 2.5 cm space between individual slabs to allow for better steam penetration.

If re-using compost material containing used potting media and discarded plants, thorough steaming should be done to minimize the disease potential.

Time-Temperature Relationships to Destroy Undesirable Organisms

The following chart gives the time/temperature relationships necessary to destroy undesirable organisms. It shows that most organisms of concern to growers can be eliminated under ideal conditions of 60°C for 30 minutes.

Weeds (most)	70°C–80°C for 15 min.
Bacteria (most)	60°C for 10 min.
Fusarium	57°C for 30 min.
Botrytis	55°C for 15 min.
Nematodes	55°C for 30 min.
Rhizoctonia	52°C for 30 min.
Sclerotinia	50°C for 5 min.
Pythium	46°C for 40 min.

When soil temperatures rise above 82°C, beneficial soil organisms begin to be destroyed. If the soil is heated to too high a temperature for too long a time, it becomes sterile. It is then subject to a greater degree of infection than previously, as all beneficial organisms have been destroyed. There are many other undesirable effects of over-steaming, such as:

- excessive ammonia release
- manganese toxicity
- higher total salt levels
- destruction of organic matter

Aerated Steam

Aerated steam is being used more widely today for soil used in potting mixes. In this system, steam mixes with air in a chamber. The mixture is used at 70°C to pasteurize soil while avoiding any of the hazards of over-steaming. Unless there are specific problems, a soil temperature of 70°C is adequate for most insect and disease problems.

Electric Soil Pasteurizers

Electric soil pasteurizers are useful when pasteurizing small volumes of soil or when no other method is available. Note that these can overcook the soil very easily. For the soil temperature between the finned heat sources to reach 82°C, the fins themselves must be at a higher temperature. Media must be moist to better conduct the heat.

Chemical Fumigants

Chemical fumigants such as Basamid, methyl bromide, Telone, Vapam and Vorlex can be used for pasteurizing soil for potting or in greenhouse beds or benches but are rarely used today. Each of these fumigants has a specific rate and activity against soilborne insects, diseases, nematodes and weeds. Note that some formulations may be less effective against certain types of pests — always read the manufacturer's label. Protect crops in adjoining beds or benches from accidental exposure to escaped fumes.

Fumigants listed in Table 6–1. *Chemical Fumigants for Soil Treatments*, are effective as preplanting treatments for greenhouse soil beds. The amounts shown are for use on 100 m^2.

TABLE 6-1. Chemical Fumigants for Soil Treatments

Control of Nematodes Only	
Product	Rate (per 100 m^2)
Telone IIB	2.0 L
Telone C-17	2.0 L
Vorlex Plus	2.5 L
Control of Nematodes, Fungi, Insects and Some Bacteria	
Basamid (granular)	3.25–5 kg worked into a depth of 15–23 cm
Vapam (liquid)	10 L
Vorlex Plus (liquid)	6 L
Methyl bromide/Chloropicrin	Pressurized cans 98%/2%: 7.5–10 kg Injectable 68%/31.8%: 2.5–3.65 kg

Notes on Methyl Bromide

Methyl bromide must be applied only by applicators licensed by the Ministry of the Environment. The bromide residue that lingers in the soil after using methyl bromide may reduce the germination and/or growth of salvia, dianthus, ageratum, alyssum, antirrhinum, aster, calendula, celosia, chrysanthemum, cleome, coleus, coreopsis, dahlia, digitalis, godetia, helichrysum, iberis, lobelia, matricaria, myosotis, nemesia, nierembergia, portulaca, salpiglossis, verbena, vinca, and viola.

Do not use methyl bromide prior to planting a lettuce crop or other leafy vegetables.

Weed Control

Control of weeds inside and outside the greenhouse is an important part of any pest management program. Weeds can act as a reservoir for diseases. A 5-metre vegetation-free or carefully maintained strip of lawn around and between greenhouses will also decrease the danger of diseases from outside blowing in.

Herbicide application, cultivation and mowing are the most practical methods of controlling weeds around the perimeter of the greenhouses. Herbicides such as Roundup or Gramoxone are very effective. See *Herbicides* below for additional comments.

No herbicides are registered for use within the confines of the greenhouse. Remove weeds when young to prevent seed production from occurring. For bedding plant production facilities, covering the surface of the soil with black nursery mesh will minimize weed growth.

Steam

As mentioned above, steam used to pasteurize soil will kill weeds and most weed seeds if the soil temperature can be held at 70°C–80°C for 15 minutes. Weed seeds in the soil along the periphery of the steam tarpaulin and weed seeds with hard seed coats may not be killed.

Soil Fumigation

Metam sodium (Vapam), dazomet (Basamid) and methyl isothiocyanate (Vorlex) are useful in treating seedbeds and potting soil. They break down in the soil to produce a gas that kills many weed seeds, nematodes and fungi that cause damping-off and other plant diseases. Do not use when plants are in other areas of the greenhouse.

Methyl bromide is also effective for weed control and general soil sterilizing. It comes as a liquid and forms a poisonous gas when released from the container. Methyl bromide must be used by licensed applicators only, under a gas-proof cover, usually plastic.

Herbicides

OMAFRA Publication 75, *Guide to Weed Control*, contains information on herbicides registered for use in Ontario. Treatments listed in the publication are subject to extensive field trials and observation on farms. Herbicides may be particularly useful for weed control outside but no herbicides are registered for use inside the greenhouse.

Do not use any phenoxy type herbicides or lawn fertilizers impregnated with herbicide adjacent to the vent side of the greenhouse because of the volatility of these herbicides.

There is potential for crop damage if any herbicide is used incorrectly. Always turn fans off so as not to draw herbicides into the greenhouse. OMAFRA Resource Centres and Government Information Centres have copies of Publication 75, *Guide to Weed Control*. Carefully follow the instructions in regard to chemicals, safety precautions, calibration and care and use of sprayers.

Where unwanted herbicide residues remain in soil, application of activated charcoal can reduce the problem. The rate varies depending on the type of chemical contaminant and its concentration. A usual range is 0.5–1.5 kg/100 m^2.

Pathogen-Free Plant Material

Purchase cuttings from specialized propagators or from plant breeders to minimize the chance of introducing diseases into a greenhouse operation. If possible, isolate new plant material to reduce the potential for contamination.

Change stock plants regularly. This may mean quarterly or every six months, depending on the crop. Do not carry stock of any bedding plants from one season to the next.

Don't bring in clean stock until the old has been moved out and the area thoroughly sanitized. Alternatively, isolate the clean stock in a separate area.

Vector Control

Many viruses and viroids are spread by insects. For example, aphids spread Aster Yellows in chrysanthemum while TSWV/INSV is transmitted by western flower thrips. Consider using screening on open cooling vents to block many insect pests from the greenhouse. This makes control of the insect population easier.

Fungus gnats are now known to spread the spores of *Pythium*. The larvae damage young roots through feeding activity. Research has shown that *Pythium* oospores (thick-walled sexual spores) are routinely transmitted through the gut of fungus gnat larvae. As well, the adult can transfer the pathogen with its legs and mouthparts. Controlling algae growth and providing adequate drainage under benches helps control fungus gnats and shorefly populations and minimizes the spread of disease pathogens.

Host Plant Resistance

Many plant species display varietal differences in their susceptibility to insect and disease attack. Breeding of crops can provide growers with cultivars resistant to one or more insects or diseases. For example, greenhouse tomato growers seldom experience problems with *Fusarium* crown and root rot because resistant varieties have been developed. Powdery mildew–tolerant cucumber varieties are increasingly used by greenhouse growers. Although ornamental plant breeders have not taken great advantage of host plant resistance, it offers potential for future advancements in pest management.

In the meantime, growers with pest problems can improve their pest management program by looking closely at the varieties grown and at how these varieties are affected by pests. Use susceptible varieties as indicators for pests and diseases. Spot-spray the susceptible variety when pests or diseases occur to provide effective control and reduce the amount of pesticide applied. Although market demands determine the varieties grown, it may be possible to eliminate or reduce the amount of a susceptible variety and replace it with a more resistant one.

Some cultivars of crops are less susceptible to certain diseases than others. Plant breeders are beginning to use plant breeding to introduce disease resistance into crops.

Chemical Control

Fungicides have been the conventional approach to disease control. The role of fungicides can vary from protecting healthy plants to treating infected plants and eradicating diseases. Rotation of fungicides with different modes of action is necessary to reduce the likelihood of resistance development. Rotation of fungicides has become increasingly important as most newer fungicides have a single-site mode of action and are more prone to resistance development. Reducing the use of and reliance on fungicides is also critical in resistance management. An important aspect of fungicide use reduction is developing a better understanding and appreciation of the role of cultural practices in disease management.

Soil Drenches

Soil drenches are typically used for the control of root or crown attacking disease pathogens and involve the application of the pesticide to the root zone. The amount of pesticide added varies depending on the pot size and volume of the growing medium, but to thoroughly wet the growing medium in a 15 cm pot, requires approximately 150–180 mL. For soil beds, apply 12 L of drench per m^2.

Be aware that not all pesticides require the medium be completely wet, so follow the label directions carefully.

Application of soil drenches for crops being subirrigated is a challenge because the roots are all concentrated on the bottom of the pot while the fungicide is being applied from the top and secondly because by applying from the top, the accumulated salts in the top zone of the media are pushed down into the active root zone area, potentially compounding the problem. Discuss options available with the Greenhouse Floriculture Specialist or IPM Specialist.

Growing media should be moist not dry when fungicides are applied to avoid further damage to the root systems of the crop.

For disease control, drenches should not replace a thorough greenhouse pasteurization program but they are useful for preventing recontamination or eliminating pathogens in the soil or the basal parts of the plant.

Some fungicides are taken up from the soil by plant roots and distributed throughout the plant. This is described as systemic action, and the whole plant is effectively treated against the disease being targeted. Aliette is the only fungicide effective against a root and crown pathogen that is more effective when applied to the foliage and is translocated downward.

Use of a root inspection-monitoring program as the first line of defence against root diseases is highly recommended wherever possible.

Biological Control of Diseases

Biological disease control involves the use of naturally occurring fungi and bacteria that strongly suppress disease-causing organisms without harming the crop. Mechanisms of action include competition, antibiosis, parasitism or induced resistance. Most biocontrol products should be considered preventative or suppressive and their use started with the planting of a crop. Note that labels indicate "suppression of disease" not "control of."

Three microbial fungicides, Mycostop, Rootshield and Sporodex, have received Canadian registrations for use on greenhouse crops in the last five years but only the first two are currently available.

Mycostop is registered for the 'suppression' of Damping off caused by *Pythium*, root and crown rot caused by *Phytophthora* and wilt caused by *Fusarium* on greenhouse ornamentals. The soil bacterium *Streptomyces griseoviridis* K61 is the active ingredient. Its mode of action includes hyperparasitism (microbe deprives pathogen fungi of nourishment by colonizing plant roots in advance of the fungi, and antibiotic production, which inhibits pathogen growth. Because the effect is preventive, drench Mycostop immediately after potting and repeat the treatment every three to six weeks depending on disease pressure.

Rootshield is registered for 'suppression' of *Fusarium*, *Pythium* and *Rhizoctonia* on all ornamental crops. The naturally occurring fungus *Trichoderma harzianum KRL-AG2* strain provides protection by colonizing the surface of the roots and root rhizosphere through the utilization of waste products produced during normal root growth. It also parasitizes disease-causing fungi through the release of enzymes that cause breakdown of their cell walls. It is recommended this biofungicide be applied soon after germination, rooting or sticking of vegetative cuttings. Two formulations are available; a granular formulation that can be incorporated into the growing media or a drench to be applied to newly transplanted seedlings or cuttings.

Sporodex received registration for use on greenhouse cucumber and rose for the control of powdery mildew, but as of printing is not yet commercially available. Sporodex is a liquid suspension of spores of the fungus *Pseudozyma flocculosa*, which acts as a strong antagonist of mildew species. Studies suggest that it produces antibiotics that interfere with cell membranes. Application of Sporodex should begin as powdery mildew begins to appear and should be done weekly. It works best at 25°C and when the relative humidity is above 70%, which suggests application should be made as late in the day as possible or on cloudy, rainy days. Use a wetting agent.

Other biological control agents for disease control are in various stages of research and development and it can be expected that there will be more registrations of these types of products in the future.

As with pesticides, biocontrols are not a universal panacea for disease control. Biocontrol agents will not replace good crop management strategies.

Achieving Successful Disease Management

Successful disease management can be achieved if the these measures are followed:

- Emphasize prevention rather than cure. This is critical in any production system but is especially true when crops are being grown in closed sub-irrigation systems.
- Monitor crops weekly or (at the least) biweekly.
- Walking the crop(s) is essential to early detection. This means checking the crop foliage and root systems and both manual and computer-controlled environment conditions.
- As a grower/manager, keep detailed records that enable merging of cultural, environmental, and insect and disease data for analysis.
- Monitor the weather to help anticipate potential disease problems. For example, a cool, cloudy and wet summer with the central heating system off creates ideal conditions for downy mildew development. Poinsettia propagators can anticipate slow, uneven rooting and increased *Botrytis* rot without supplementary heating.
- The employee in charge of monitoring cannot work in a void and must work closely with the person responsible for overall crop scheduling. Ideally, the individual in charge of growing should be the one who monitors for disease and environmental control. In many operations, this should be done by an employee, not by the owner/grower.
- Correct diagnosis is crucial. Without correctly identifying the pathogen, control using cultural or chemical strategies is impossible. Soil-borne fungi are the most difficult pathogen for growers to identify. Send samples to the Pest Diagnostic Clinic, University of Guelph, for accurate diagnosis. See Appendix B for further details. For some diseases, ELISA disease diagnostic kits for grower use are available from companies such as Agdia.
- Develop a thorough understanding of the diseases that affect the crops being grown. Correct use and timing of management strategies then becomes part of an ongoing process.
- Because disease pathogens are microscopic, learn to anticipate when possible pathogen infection periods are likely to occur. By the time the problem is visible, the pathogen has usually been present for some time and is more difficult to control.

7. Major Greenhouse Diseases

Quarantine Pest Problems

This chapter describes the most common disease problems in greenhouse ornamental production. However, it is important to realize that some of the most destructive diseases are very infrequently found but when they are, the impact can be devastating. A quarantine pest is "a pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled (FAO, 2004)". Some of these pests or diseases are known to be a potential risk and are regulated by the Canadian Food Inspection Agency (CFIA). Other pests may have no known potential for damage until they occur, at which time CFIA will decide on the risk they present. If found, regulated pests must be reported to CFIA who will decide what action must be taken to address the pest problem. Although this action can have serious financial impacts on individual growers, it is important to the industry that growers report suspected problems. Failure to do so could threaten the export of ornamental plants to countries such as the United States. Known quarantine diseases as of June 2006 are noted within this chapter and include chrysanthemum white rust, Ralstonia bacterial wilt of geranium and Ramorum Blight and Dieback (Sudden Oak Death). For more information and the most up-to-date listing of regulated pests and diseases see the CFIA website at *www.inspection.gc.ca/english/plaveg/protect/listpespare.shtml* or contact your local CFIA office. See Appendix D, *Other Contacts*, on page 146.

Fungus Diseases

Botrytis (Grey Mould)

The fungus, known as *Botrytis cinerea*, causes many common diseases of greenhouse ornamental and vegetable crops. "Grey mould" is often used to describe the disease because of the prolific sporulation of grey or brown spores, a characteristic symptom that occurs on infected tissues under appropriate conditions.

Botrytis disease symptoms appear as flower spotting and blight, leaf blights, bud and cutting rot, stem cankers, and corm or bulb rots.

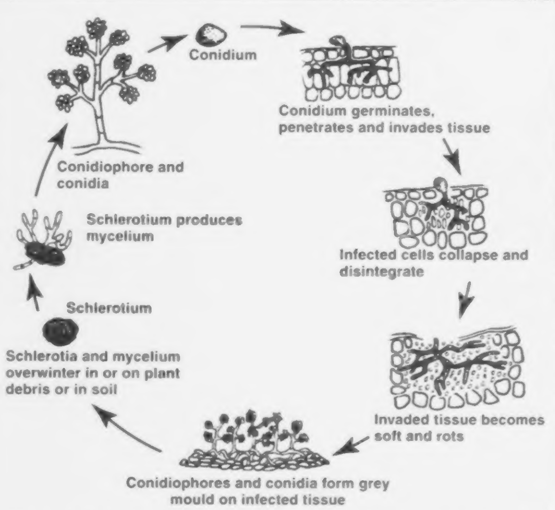
Infections occur when germinating conidia (spores) penetrate healthy succulent leaf or flower tissue, stomata, or wounds, or when pieces of fungal mycelium or infected plant tissue come in contact with healthy host tissue. See Figure 7–1. *Botrytis Life Cycle.*

Botrytis readily attacks healthy or senescing soft, nutrient-rich flower or bract tissues of cyclamen, geranium, rose or poinsettia. Mycelial infections typically occur when infected flowers or leaves fall onto healthy tissues below and become appressed to wet leaf surfaces.

Latent infections occur as described above but show no visible symptoms because of unfavourable environmental conditions. When environmental conditions change, symptoms may appear. This typically occurs with cut flowers, which appear healthy when packed but have tan-brown spots on the petals when unpacked.

Botrytis is ubiquitous — the spores are always present. The conidia disperse very readily in air currents and in or on water droplets. Fluctuating relative humidity levels trigger the release of spores. Spore germination can occur in less than three hours, with sporulation occurring in eight hours.

FIGURE 7–1. *Botrytis* Life Cycle


Conidium
Conidium germinates, penetrates and invades tissue
Infected cells collapse and disintegrate
Invaded tissue becomes soft and rots
Conidiophores and conidia form grey mould on infected tissue
Schlerotia and mycelium overwinter in or on plant debris or in soil
Schlerotium
Schlerotium produces mycelium
Conidiophore and conidia

Botrytis infections usually occur during cool, wet or humid weather conditions, which favour infection and sporulation. Free moisture containing dissolved nutrients acts with temperature to determine the initial infection and subsequent lesion development. Optimal conditions for Botrytis growth are temperatures between 15–23°C and relative humidity (RH) greater than 85% or microscopic free moisture on plant tissue.

Disease Control

Botrytis is often considered a "disease of bad management." Use appropriate crop management techniques and manipulation of the greenhouse environment to minimize its impact. For example, reduce the relative humidity at night by maintaining warmer night temperatures and proper ventilation practices.

Use computer-controlled humidity monitoring programs. Avoid formation of free moisture, which occurs at night whenever the leaf or plant temperature is lower than the air temperature or the air cools below the dew point. This happens frequently in the evening with a clear sky or early in the morning when the air heats up more quickly than the plant surface. Use minimum pipe temperatures in summer when nights are warm and humid.

Calibrate RH sensors regularly. Keep RH below 85%. Do not allow leaves to stay wet more than three to four hours.

Air circulation is critical for maintaining dry plant surfaces and usually depends on proper plant spacing. Remove excessive foliage in crop canopy if necessary.

Sanitation before and during crop production is essential. Remove senescing flowers and leaves.

Avoid overhead watering wherever possible. When overhead watering is necessary, water early in the day to allow foliage and canopy to dry before evening.

Fungal Leaf Spots, Flower Spots and Blights

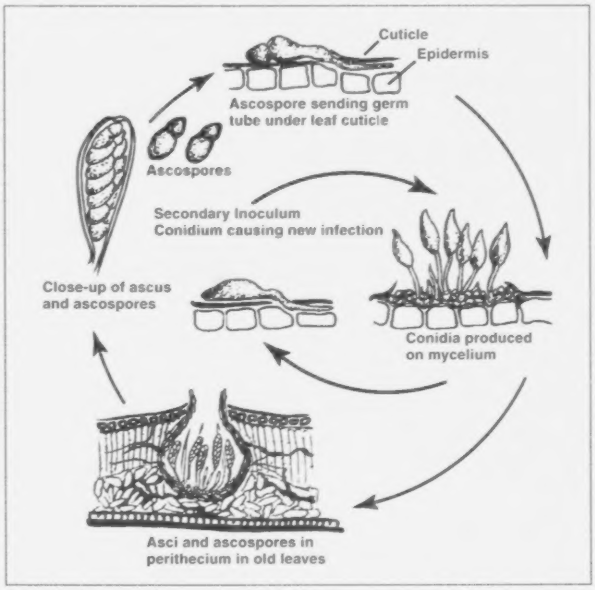
Fungi cause all of these diseases, with symptoms varying greatly. See Figure 7–2. *Leaf Spot Disease Life Cycle.*

The more common fungi-causing leaf spots include *Alternaria, Ascochyta, Cercospora, Phyllosticta, Gloeosporium,* and *Septoria.* Most produce abundant conidia. Spores of these fungi are wind-borne and can be splashed about when watering.

Blights or spots can appear on leaves, stems or flowers depending on the organism present. Many attack all three plant parts but none attacks the roots or crown. Leaf blights and spots usually appear on the lower foliage and work their way up through the plant canopy. Many of the pathogens produce characteristic spots or lesions, such as "bull's-eye" spots with a reddish border or tan-coloured spots with concentric rings. Spots may be circular, angular or irregular.

Leaves must be wet for infection to occur.

FIGURE 7–2. Leaf Spot Disease Life Cycle


Cuticle
Epidermis
Ascospore sending germ tube under leaf cuticle
Ascospores
Secondary Inoculum
Conidium causing new infection
Close-up of ascus and ascospores
Conidia produced on mycelium
Asci and ascospores in perithecium in old leaves

Disease Control

To control disease:

- Keep foliage and flowers as dry as possible.
- Avoid overhead watering.
- Provide good air circulation.
- Remove infected plant material from the greenhouse.
- Use disease-free propagating material.
- Most broad spectrum fungicides will provide effective control. Check the label for registered uses.

Powdery Mildews

These common fungal diseases cause an easily recognized white powdery growth on leaves, stems, petioles and floral parts of infected plants, quickly making plants unmarketable. Several genera including *Erysiphe, Leveillula, Microsphaera* and *Sphaerotheca* are involved. It is important to note that the fungus that causes powdery mildew on one crop generally doesn't affect another. Because powdery mildews are obligate parasites, they require living plants for completion of their life cycle. Each of these fungi forms a network of hyphae over the leaf or stem surface from which it penetrates epidermal cells to derive its nutrients via nutrient pegs known as haustoria.

Growth may begin as small, discrete spots but can spread to cover the entire upper surface of the leaves. On many plants, the fungal growth becomes felt-like. This happens when ideal conditions produce abundant superficial mycelia bearing many colourless conidia (spores). In some plants, the leaves develop a reddish discolouration where the infection occurred. Severe infections will cause leaf stunting, yellowing and curling.

In the greenhouse, powdery mildew fungi have a simple life cycle. Single-celled conidia form in a long chain on short, erect fungal stalks. See Figure 7–3. *Powdery Mildew Life Cycle.* This creates the "fluffiness" usually associated with powdery mildew. Under favourable environmental conditions, conidia chains are produced and released at a usual rate of one conidium per day or diurnal cycle. Conidia mature and are ready for release in 24 hours. A relative-humidity drop and the heating and drying effect of solar radiation promote spore release.

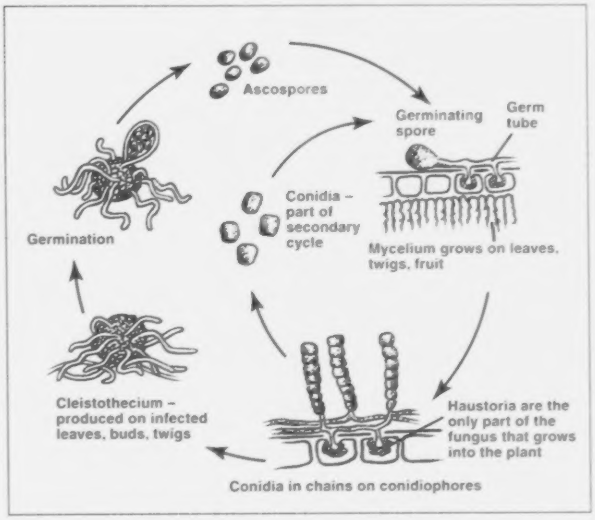
Conidia need relative humidity of 95% or near zero vapour pressure deficit for more than three to four hours, to germinate and penetrate the host's leaf or stem epidermal cells. The mycelium produces haustoria or nutrient pegs, which provide a constant nutrient supply for fungal growth and conidial stalks as it grows over the leaf surface. Within 48 hours of inoculation, mature conidia can release to infect other leaves or plants.

Relative humidity, temperature, light, leaf wetness and air movement (e.g. drafts) all influence the severity and spread of powdery mildew infections. Because of these interrelated environmental factors, use an integrated approach.

Excessive and turbulent air movements, such as drafts near open doors, improper spacing of HAF (horizontal air flow) fans or improper fan sizing or speed promote infection and spread.

Leaf wetness episodes promote fungal development. The occurrence and persistence of leaf wetness are affected by leaf-to-air temperature gradients, the degree of leaf radiant energy loss, solar radiation and leaf transpiration.

FIGURE 7–3. Powdery Mildew Life Cycle


Ascospores
Germinating spore
Germ tube
Conidia – part of secondary cycle
Mycelium grows on leaves, twigs, fruit
Germination
Cleistothecium – produced on infected leaves, buds, twigs
Haustoria are the only part of the fungus that grows into the plant
Conidia in chains on conidiophores

Disease Control

Avoid drafts by keeping walkway doors closed. Automate the opening and closing of doors if possible. Reduce speed of HAF fans if they have variable speed motors. Maintain smooth air-flow patterns over leaf surfaces. This prevents localized high relative-humidity areas and reduces air and leaf temperature fluctuations.

Use a humidity-control program. Establish reasonable parameters and use an environmental computer to maintain the desired relative-humidity levels through ventilation and heating. Avoid sudden changes in either temperature or relative humidity due to venting. High relative humidity on its own does not necessarily promote powdery mildew.

Rely on the radiant heat from both the crop-zone and above crop heating lines to maintain a drier, warmer crop environment. Establish a higher minimum pipe temperature if using hot water or apply short pulses of steam into the above crop heating lines to create a source of radiant heat.

During the evenings in late summer the dewpoint is often reached in the greenhouse as temperatures drop. Closing shading or energy curtains and/or using high pressure sodium lighting will help prevent radiant energy loss from leaf surfaces by keeping them warmer.

Downy Mildews

Peronospora, *Plasmopara*, and *Bremia* are the three downy mildew genera attacking ornamental plants. The downy mildews are becoming increasingly more common and are difficult diseases to control. These fungi are primarily foliage blights but will attack and spread rapidly into young, green tissues of growing tips and flower buds. Some of the most commonly attacked crops include rose, snapdragon, impatiens, lisianthus, sunflower, cineraria, pansy and numerous perennials.

For most crops, masses of tan, white or purple fuzz (spores) can be found on the undersurface of the leaves. Leaves of most plants will tend to cup along the margin and curl downward. Upper leaf surfaces may show chlorosis (yellowing) where the infection is located.

Their development and spread depend on the presence of water films on the plant tissues and on high relative humidity during cool periods (but not during hot periods).

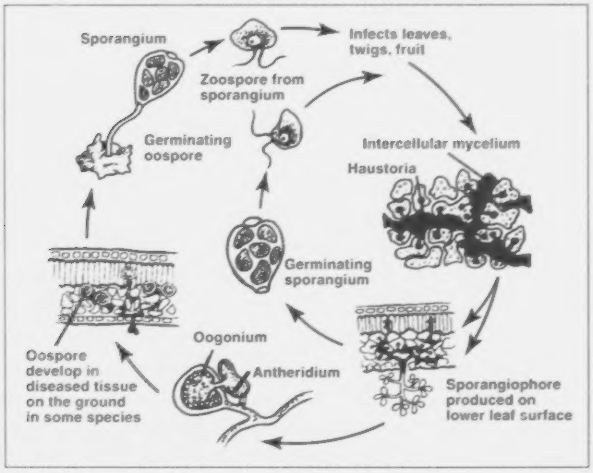
Rose leaves develop purplish-red spots on upper leaf surfaces. They may be distorted, have symptoms typical of pesticide phytotoxicity, turn yellow and abscise in great numbers. Rose downy mildew produces very few visible spores unless optimal conditions exist.

Downy mildew of snapdragons produces masses of grey-brown spores that look like thick velvet. Foliage becomes distorted and if infection occurs in the seedling stage, it quickly becomes systemic and infects the growing tip or developing flower spike. Losses can be severe.

On impatiens, yellow stippling similar to spider mite injury is commonly observed

Downy mildew fungi can survive on infected plant debris in the soil or on weed hosts.

FIGURE 7–4. Downy Mildew Life Cycle


Sporangium
Infects leaves, twigs, fruit
Zoospore from sporangium
Germinating oospore
Intercellular mycelium
Haustoria
Germinating sporangium
Oogonium
Antheridium
Oospore develop in diseased tissue on the ground in some species
Sporangiophore produced on lower leaf surface

Sexual reproduction causes oospore production, which carries the fungus through periods unfavourable for vegetative growth. See Figure 7–4. *Downy Mildew Life Cycle.*

Disease Control

Manipulating the environment combined with fungicide applications can prevent further spread to non-infected plants. Fungicides won't cure systemic plant infections.

Control the relative humidity and temperature fluctuations to prevent moisture condensation on the plants. This is often difficult when growing cool season crops. However, increasing night temperatures using crop heating and raising minimum night temperatures to reduce the radiant energy loss from leaf surfaces may achieve this.

Avoid wetting the foliage when irrigating. Spores are spread by splashing water and air currents. Water early in the day when possible.

Clean up all crop debris and infected plants and remove everything from the greenhouse, as the organism survives between crops on plant debris.

Many epidemics begin during extended periods of cool, damp weather, when growers attempt to economize on fuel consumption by adopting low temperature set points or turning off the heating system during the late spring or early fall periods.

Fungal Wilts

Wilt diseases cause a whole plant, a portion of a plant or a major branch to wilt. Other symptoms include vascular discolouration, stunting and varying degrees of leaf yellowing. Infectious wilts divide into two broad categories:

- Fungal, caused by *Fusarium solani, Fusarium oxysporum* and *Verticillium albo-atrum.*
- Bacterial, caused by *Erwinia chrysanthemumi, Erwinia carotovora, Xanthomonas campestris* and *Ralstonia solanacearum.* For discussion on bacteria, see page 87.

Most fungal wilt pathogens are soil-borne, attacking through roots or the crown area. Root hairs and root tips exude nutrient-rich compounds like proteins and enzymes into the media. These stimulate fungal germination and are the first nutrient source for potential pathogens until they are established within the plant host. Bacterial pathogens also need a wound or natural opening (such as stomata or hydathodes of leaves) for invasion.

Fungal wilt pathogen growth is limited to the vascular tissue, while bacterial pathogens spread rapidly into adjacent tissues through maceration (breakdown) of all cell tissue. Both groups of pathogens can be carried in the stems of symptomless cuttings.

Symptoms of *Fusarium* and *Verticillium* are almost identical in some plants and can only be accurately identified through laboratory examination. These pathogens plug the xylem vessels, interfering with the translocation of water and nutrients. Symptoms include wilting, marginal necrosis and yellowing (and eventually browning) of older leaves. Plants are usually stunted, bloom production is reduced and the vascular tissue often has a brownish or reddish-brown discolouration. Plants usually die, particularly from an early infection. Many weeks can pass between the initial infection and the appearance of symptoms.

Fusarium can cause stem and crown rots that result in wilting and collapse. The dark-brown to black lesions develop on the stem at, or just below, the soil line, with the leading edge often pinkish or reddish. Infection occurs inward — there is usually no external stem discolouration.

Fusarium is a very common pathogen of a wide range of greenhouse crops. *Verticillium* is much less common, and usually attacks only chrysanthemum, aster and dahlia.

The fungal pathogens persist for long periods as thick-walled resting spores in soil or plant debris. The spores form when plant tissue begins to dry up. Host plant stress makes plants susceptible to a fungal wilt pathogen attack and strongly influences attack severity. Stress can include high or low air or media temperatures, or improper watering, nutrition, media pH or EC.

Pathogen spread during propagation is very common. Fungal pathogens are readily spread by water movement through media, splashing and the physical movement of infected media and plant material within and between greenhouse operations.

Fungus gnat larvae readily spread *Fusarium spp.* spores.

Disease Control

To control disease:

- Use pathogen-free cuttings and seeds.
- Remove and destroy all infected plants.
- Sanitize benches and used trays. Do not reuse pots.
- Thoroughly pasteurize beds for soil-grown crops.
- Maintain good horticultural practices.

Damping-off of Seedlings

Rhizoctonia solani, *Pythium spp.* and *Phytophthora spp.* are the primary causes of this disease, which describes a condition affecting germinating seeds and young seedlings. See Figure 7–5. *Disease Cycle of Damping-off and Seed Decay.* However *Fusarium*, *Botrytis* and *Sclerotinia* are occasionally responsible.

Pre-Emergence Damping-Off

Pre-emergence damping-off kills the emerging radicle and hypocotyl during germination or soon after emerging from the seed coat. The young plants never emerge from the media. Growers often mistakenly blame this loss on poor seed.

Post-Emergence Damping-Off

Most growers are familiar with post-emergence damping-off. Typically, the stem is invaded at or near the soil surface. The seedling wilts or stunts, the stem collapses and the plant topples over. Stem lesions may appear somewhat water soaked. Other variations of post-emergence damping-off include top rot or top damping-off and root rot.

Wire-Stem Damping-Off

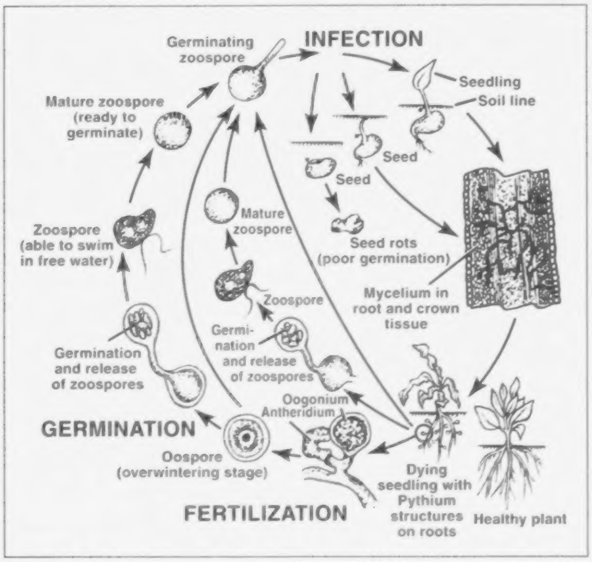
Wire-stem damping-off is usually associated with older seedlings that have been hardened off. Stems are partially girdled with dry, black lesions and a wire-like appearance. Infected plants are stunted and eventually die. *Rhizoctonia* is usually associated with this condition.

Rhizoctonia often spreads in a circular pattern in a seedling tray, with fine grey-brown strands of mycelium visible on the surface of the growing media or as an aerial blight infecting the above-ground plant parts.

Water moulds like *Pythium* and *Phytophthora* can attack seeds but commonly induce rot from the tips of the young roots. This is most severe at high moisture levels and cool temperatures.

Wet media, poor sanitation, poor ventilation, high humidity, cool temperature, thick stands of seedlings or overgrown seedlings are ideal conditions for damping-off fungi.

FIGURE 7–5. Disease Cycle of Damping-off and Seed Decay


INFECTION
Germinating zoospore
Mature zoospore (ready to germinate)
Zoospore (able to swim in free water)
Germination and release of zoospores
GERMINATION
Oospore (overwintering stage)
FERTILIZATION
Oogonium
Antheridium
Germi- nation and release of zoospores
Zoospore
Mature zoospore
Seedling
Soil line
Seed
Seed
Seed rots (poor germination)
Mycelium in root and crown tissue
Dying seedling with Pythium structures on roots
Healthy plant

Disease Control

To control disease:

- Sanitation is important. These pathogens can spread due to dirty seedling trays, infested media and dirty tools. Remove all infected seedling trays.
- Avoid splashing water, which will spread the pathogens.
- Use only new flats or plug trays for disease-susceptible crops.
- Use a porous, well-drained seedling mix.
- Maintain proper temperatures throughout the various phases of seedling germination and growing on.
- Provide good air circulation.
- Don't contaminate media used for seeding with dust or used media.
- Reduce misting as soon as possible after seedling emergence.

Crown and Root Rots

The fungi that most commonly cause crown and root rots are, in order of importance, *Pythium*, *Rhizoctonia*, *Phytophthora*, *Fusarium*, *Thielaviopsis* and *Sclerotinia*. Crown and root rot fungi are soil-inhabiting pathogens that constantly threaten commercial greenhouse crops. Note that each of these disease-causing fungi has unique environmental needs.

"Root rot" is a general term for the killing and then rotting of roots by various fungi. Root rot begins when the cortical roots become dysfunctional. They appear water-soaked and have a brown to black discolouration. New root development is reduced. As the rot progresses, the leaves become yellow and stunted; eventually they wilt.

Root rots debilitate individual plants and groups of plants. They compromise crop uniformity and often cause symptoms of nutritional imbalance. This is a serious issue with crops being grown in closed sub-irrigation systems.

Root pathogens are more difficult to diagnose visually than most foliar diseases.

Disease Control

All fungal root rot pathogens can survive in growing media or on infected tissues as mycelium or spores. They can also exist in the soil as *oospores, chlamydospores* or *sclerotia*, (resting structures with thick cell walls) that remain viable for long time periods. When they contact roots of a susceptible host, they become active (germinate) and begin infecting root tissues. Completely eliminating the inoculum source is difficult, so preventing their activity is the key to control.

All root rot fungi can be spread by splashing water and irrigation water. Fungi can also be carried over in contaminated media, soil under benches, infested plant residues, dirty containers, blowing dust, used capillary mats and recirculated irrigation water.

Healthy plants resist root rot infection. Crop stress is the leading environmental cause of crown and root rots, predisposing plants to attack. Factors contributing to crop stress include fertility level, EC, media pH, watering practices, temperature, light level, and pesticide and growth-retardant application. Each root pathogen has a different optimum temperature, pH and moisture requirement.

Irrigation water from storage ponds collected from runoff may contain root rot pathogens.

Most artificial media are considered pathogen-free, and have few naturally occurring fungi or bacteria to act as suppressive agents.

Pythium spp.

Pythium root rot is the most common root rot found in greenhouse production. Several different species including *P. ultimum* (the most common) *P. aphanidermatum and P. irregulare* attack many crops.

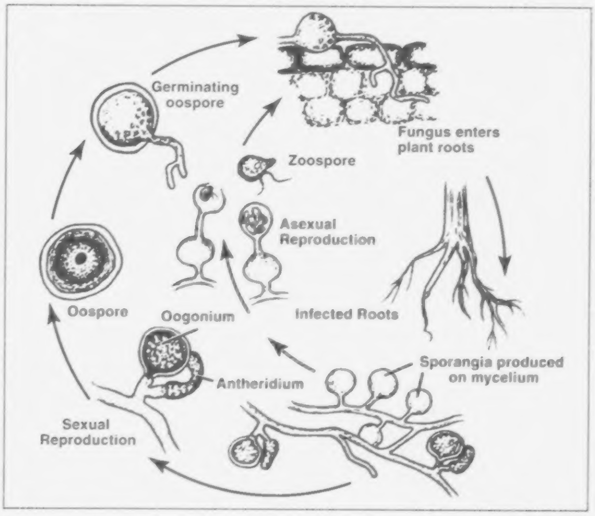
Symptoms vary with the age and development stage of the affected plant. Older-plant infections are usually limited to roots and root hairs. Infected roots are soft, mushy and various shades of brown. The rot begins as water-soaked brown rot of the root tips and cortex. Usually the cortex sloughs off, leaving the vascular cylinder (which remains thread-like). Lesions can occur on crowns of more succulent crops such as gloxinia. Above ground symptoms include stunting, wilting and yellowing due to nutrient and water deficiencies. *Pythium* black leg of cuttings is generally very black and often shiny.

Pythium spores germinate in response to root exudates. These provide food until the white, slender, profusely branching and rapidly growing mycelium penetrates the roots. See Figure 7–6. *Pythium Root Rot Life Cycle. Pythium*, depending on the species, quickly produces two types of spores:

- Asexual zoospores, which, when released, can swim in films of water until they contact healthy host tissue. There they germinate and start a new infection.

- Sexual oospores, which are thick-walled and resist both high and low temperatures and remain viable for long periods of time.

FIGURE 7–6. *Pythium* Root Rot Life Cycle



Regardless of species, spores are moved around rapidly within a greenhouse in irrigation water.

Disease Control

Pythium ultimum infections are most common at temperatures below 18°C while other species favour high temperatures. Maintain temperatures favourable for plant growth, particularly root growth. High media temperature causes considerable root stress and is of concern during the summer months when growing on concrete floors and troughs.

Avoid overwatering when the crop is young or is not growing actively. Use a porous, well-drained media.

Keep the EC of the media low during the summer. Check regularly for high salts. Avoid excess nitrogen fertilization.

Monitor and control fungus gnat populations. Both fungus gnat larvae and adults can spread the pathogen.

Rhizoctonia

Rhizoctonia solani is commonly associated with damping-off but can also occur in rooted cuttings and well-established plants of most commercial floriculture crops.

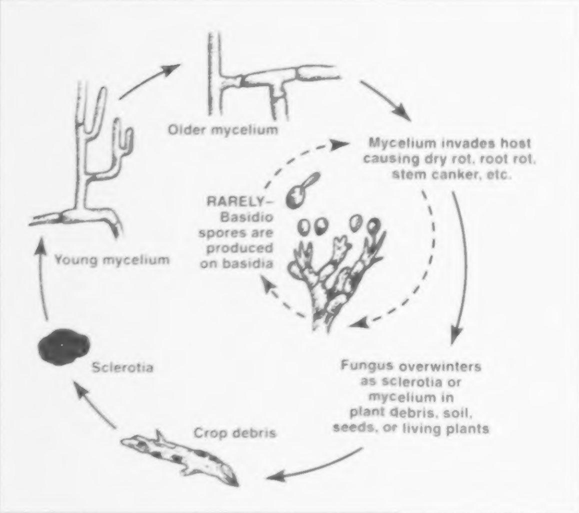
The symptoms vary with the host and development stage but generally cause reddish-brown lesions on the below ground stem and roots of infected plants. Under favourable conditions, the lesions increase in size and number to include the whole base of the plant. See Figure 7–7. *Rhizoctonia Life Cycle.*

This pathogen is slow to girdle the crown and root area of established plants. As a result, the grower may not observe this disease until long after the initial infection when plants begin to wilt or appear stunted with yellowing leaves. Lower leaves of infected plants usually become chlorotic and plants may break off at the soil line.

Potted plants propagated by cuttings such as geranium, poinsettia and New Guinea impatiens are susceptible. It appears as a brown basal rot and stems may have longitudinal cracking. Crown rot can occur as a crown infection in the absence of root rot.

On fleshy, succulent stems, bulbs, and corms, the brown or black sunken lesions are often dry. Stem cankers can occur on lower branches where infested media have been splashed.

FIGURE 7–7. *Rhizoctonia* Life Cycle


Older mycelium
Mycelium invades host causing dry rot, root rot, stem canker, etc.
RARELY– Basidio spores are produced on basidia
Young mycelium
Sclerotia
Fungus overwinters as sclerotia or mycelium in plant debris, soil, seeds, or living plants
Crop debris

Disease Control

High media and air temperatures and high relative humidity promote *Rhizoctonia* in most greenhouse crops. Wet or dry extremes in the growing media will enhance *Rhizoctonia* development. Temperatures of 17–26°C are optimal for this pathogen.

Phytophthora spp.

Phytophthora causes root and crown rots (similar to *Pythium*) and occasionally leaf blights. In Ontario, these pathogens are most commonly observed during the summer growing period.

Two common species, *P. cryptogea* and *P. parasitica* will attack many crops but the symptoms observed are similar. *Phytophthora* like *Pythium*, is a water mould — the asexual spores and mycelium spread quickly in films of water.

Typical symptoms include necrotic brown to black lesions on larger roots and on the crowns. Basal cankers with black streaking often appear. Leaves can become infected by contact with infested media.

Zoospore production and development are stimulated by saturated media and root exudates.

Disease Control

Avoid overwatering when the crop is young or is not growing actively. Sub-irrigated crops may require routine overhead waterings to flush plant exudates from the media. Use a porous, well-drained, pathogen-free media.

Avoid saturated media conditions. Water management is very important.

Avoid media temperatures above 26°C.

Ramorum Blight and Dieback (Sudden Oak Death)

Ramorum blight and dieback is a serious disease caused by *Phytophthora ramorum* that has killed hundreds of thousands of oak trees in California and Oregon since first being detected in the mid-1990's. It has a wide host range with dozens of genera of plants (all species in each genus) including many common nursery-grown woody ornamentals, currently regulated by CFIA. The disease has been detected in BC but has been subject to an eradication program by the Canadian Food Inspection Agency (CFIA). Strict regulatory control measures are in place to ensure the disease does not become established in Canada.

A wide range of symptoms are caused by the pathogen depending on the host, ranging from rapid decline and dieback of oak to foliar blights and leaf spots on rhododendron and camellia.

Evidence suggests that *P. ramorum* spreads by airborne spores and wind-blown rain. Cool temperatures with relatively high moisture favour disease development.

Two mating types are known to exist: the A1 or European strain and A2 or North American type.

To view the latest phytosanitary regulations to prevent entry of this disease into Canada go to *www.inspection.gc.ca/english/plaveg/protect/dir/d-01-01e.shtml*.

Fusarium spp.

Several *Fusarium* species cause stems, crowns, corms, bulbs and tubers to rot. The primary culprits are *F. solani* and *F. oxysporum*.

With root rots, the infected tissue is usually dark red to brown and may appear as streaks up to the soil line. Plant growth is usually retarded. As infection increases, the oldest leaves begin to yellow, and younger leaves become flaccid.

In stem rots affecting plants such as chrysanthemum and carnation, the infected plants wilt and die from a dry stem rot at the base of the plant. The lesions that develop at or just below the soil line often have pink or red edges leading to the infections. The lesions develop inward. There is usually no external stem discolouration.

Bulb and corm rots can occur in the field and in storage. The rot usually begins at a wound or at the base of these organs and may not produce visible symptoms. However, the basal plate and fleshy scales will be brown and decaying, with mats of mycelium. The foliage often turns purple or yellow and dies prematurely.

Disease Control

Crop stress, which is the leading environmental cause of *Fusarium* disease, predisposes plants to attack by this fungus. Standard disease control strategies apply. Review production practices and modify them as needed to minimize crop stress.

Maintain proper temperatures, avoiding high air and substrate temperatures. Avoid over-fertilization when crops are under stress.

Irrigate consistently. Wet or dry extremes enhance *Fusarium* development. Drought stress can result in the onset of rapid symptoms.

Use pathogen-free media. Use only new pots and trays to avoid contamination. Pasteurize the soil for effective control in soil-grown crops and use healthy, disease-free stock for vegetative propagation purposes.

Finally, use preventative fungicide applications during periods of unavoidable crop stress.

Thielaviopsis basicola

Thielaviopsis basicola causes a severe, black root rot of a number of major greenhouse flower crops. These include cyclamen, fuchsia, geranium, kalanchoe, primula, petunia, pansy, poinsettia and vinca.

Infected roots usually develop black lesions covering all or part of the root. Root tips may turn black. Plants are often stunted, with yellow or white leaves typical of a severe nutritional deficiency. The roots die rapidly, causing plant death.

Disease Control

To control disease:

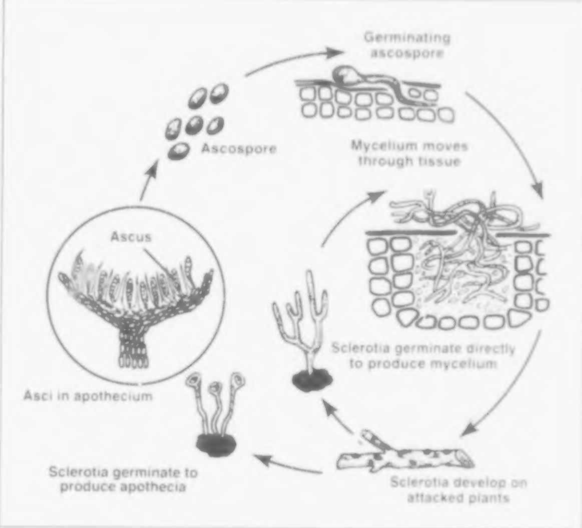
- Monitor the growing media. *Thielaviopsis* thrives with high media moisture and a high pH. Cool media temperatures (15–16°C) favour development of this pathogen.
- Avoid temperatures too high or too low for the crop. For example, do not grow vinca below 20°C.
- Avoid high ammonium nitrogen fertilization, which promotes a *Thielaviopsis* attack.
- Maintain good sanitation.
- Use pathogen-free media and monitor pH regularly.
- *Thielaviopsis* is hard to eradicate when crops are grown on the ground or wooden benches. Fortunately, this disease is not common.
- Use only new containers for growing highly susceptible crops.

Sclerotinia

Sclerotinia sclerotiorum attacks many herbaceous ornamental and vegetable crops, including chrysanthemum, snapdragon, salvia, dahlia, delphinium, tomato, pepper and eggplant. The disease is most common outdoors but is observed occasionally in the greenhouse.

Symptoms vary with the host, the affected host part and the environmental conditions. The most obvious early symptom is fluffy, thick, white mycelium on the stems of plants near the soil surface. See Figure 7–8, *Sclerotinia Life Cycle*. Relatively large, hard, charcoal-black, resting fruiting structures (called sclerotia) soon appear. These are embedded in the mycelium or in the pith of plant stems. The fungus causes a stem rot, which eventually leads to wilting and death of the plant.

FIGURE 7–8. ***Sclerotinia*** **Life Cycle**


Germinating ascospore
Ascospore
Mycelium moves through tissue
Ascus
Sclerotia germinate directly to produce mycelium
Asci in apothecium
Sclerotia germinate to produce apothecia
Sclerotia develop on attacked plants

During the early infection stages, no visible signs of infection appear on the foliage until the fungus grows completely through the stem. The exception is when the initial infection occurs through a leaf.

Sclerotinia fungus survives either as sclerotia in the soil or plant debris for at least three years or as mycelium in dead or living plant material. Sclerotia are very resistant to extreme temperatures and moisture.

Disease Control

Pasteurize the soil for effective control in soil-grown crops. For bench-grown crops, control can be difficult. Maintain dry foliage by minimizing overhead watering and dripping and provide good air circulation through the crop canopy.

This disease is most problematic in spring and summer because day length influences its activity.

Rusts

Rust fungi are obligate parasites and as such are specific to the greenhouse crop on which they are found. Some rusts found outdoors require an alternative host to complete their life cycle, however, this is not the case for rusts found on greenhouse crops. Their life cycle is complex producing up to five different spore types. Rust may occur on carnation, chrysanthemum, fuchsia, geranium, poinsettia, snapdragon and many outdoor perennials including columbine, daylily and rose.

Rust diseases produce masses of white, yellow, orange or brown to reddish-brown uredospores on the undersurface of leaves and stems. These appear when the pustules erupt to release the mature spores. First symptoms usually appear within five to seven days of infection, depending on environmental conditions.

The various rusts can produce concentric ring patterns. These rings are due to a series of environmental conditions conducive to secondary and tertiary infections. The leaf surface directly above the pustule is usually yellow and may be sunken. Numerous infection sites on a leaf will cause yellowing and eventually senescence, of the leaf. The lower leaves are usually infected first. Plants are rarely killed.

Temperature and relative humidity are critical to development and reinfection rate.

Rust spores spread via air currents and by splashing water within a greenhouse. Spores can travel long distances on the leaf surfaces of cuttings. A film of water must remain on upper leaf surfaces for at least three to four hours for spore germination and infection. However, sporulation is on the undersurface.

Rust fungi survive as spores, as systemic mycelium on or in dormant plants and in plant debris.

Disease Control

Chrysanthemum white rust is the only quarantinable rust disease of greenhouse ornamentals. Chrysanthemum white rust appears as creamy-coloured pustules on the undersurface of the lower leaves. For further information on the disease and the latest policy directive go to the CFIA website at *www.inspection.gc.ca/english/plaveg/pestrava/pucbor/pucbore.shtml* or contact your local CFIA Inspection office.

Growers who receive imported chrysanthemum stock from the United States that they suspect is infected should contact the Canadian Food Inspection Agency.

Controlling rust diseases is difficult. Most produce more than one type of spore and infected plant residue (e.g. under benches) can harbour the spores for long periods.

A temperature range of 10°C–25°C favours spore production of most rusts and spores are released into the air more readily with diurnal relative-humidity fluctuation.

Infections are often severe near fans and in corners of the greenhouse. Severe infections also occur under conditions of poor air circulation and temperature stratification due to crowding or a heavy canopy.

Avoid overhead watering or late-afternoon watering. Space plants to allow better air movement within plant canopies.

Prevent dew formation on plants by providing adequate heating, ventilation and air circulation at night to control relative humidity around and through the plant canopy.

Destroy all seriously infected plants to reduce the inoculum level.

Bacterial Diseases

Bacteria are single-celled organisms that multiply rapidly under ideal temperature conditions. Their rate of development and spread increases with temperature, moisture availability and food supply.

Some plant pathogenic bacteria attack only one or two plant species; others attack a wide range of plants. Plants commonly attacked by bacteria include geranium, begonia, chrysanthemum, calla lily and hibiscus.

Bacterial infections may appear as wilts, stem and root rots, leaf spots, galls and fasciation of plant parts. Although bacterial diseases are less common than fungal diseases, they can be very destructive and difficult to control. *Erwinia, Pseudomonas, Ralstonia* and *Xanthomonas* are the most common disease-causing bacteria affecting greenhouse crops. The bacteria can live on or in roots, leaves and stems of hosts, and in non-host plants.

Bacteria do not produce spores. Most bacteria survive in the greenhouse in a semi-dehydrated state, infecting plant debris for extended periods of time. However, *Ralstonia* survives in soil without association with plant tissues for long periods of time. See more details in *Ralstonia solanacearum*, on this page.

Bacteria enter wound sites and natural plant openings such as stomata and hydathodes or root hairs. A film of water is usually required for a bacterial infection to begin on above-ground plant parts.

With bacterial wilt infections, wilting of entire leaves or leaf margins is the first symptom. Infections typically become systemic very quickly, moving through the leaf veins and petioles. Entire leaves yellow or develop large, V-shaped yellow lesions. When bacteria invade the stems, the outside of the stem usually appears grey-black and water-soaked, while the internal stem tissue appears black.

Bacterial disease development is enhanced by high air and media temperature and by high relative humidity. Bacteria survive only in living or decaying plant material.

Pathogen spread during propagation is very common. Water movement through media, splashing and the physical movement of infected media and plant material within and between greenhouse operations spread bacterial pathogens.

Disease Control

No chemical controls will eradicate bacterial diseases from infected plants in a production environment. Prevention is the key. Good cultural practices and careful sterilization procedures reduce the chance of bacterial infection.

Purchase disease-free stock from the plant breeder for propagation purposes and isolate stock plants in a thoroughly disinfected area. Disinfect cutting tools and propagation areas frequently.

In general, warm temperatures (above 25°C) are required for bacteria to develop rapidly.

Bacteria are spread on leaves and stems by condensation, splashing water, and during pruning or harvesting of cuttings. These diseases can spread very rapidly on propagation benches and in sub-irrigation systems.

Both fixed and organic copper sprays are reasonable protectants against bacterial diseases. However, they are not eradicants and may cause phytotoxicity.

Erwinia carotovora

Erwinia carotovora causes soft-rot symptoms that first appear to be just water-soaked but quickly break down into a foul-smelling, mushy rot resulting in complete collapse of the plant. This disease thrives in warm, humid conditions. Increased irrigation and high levels of both phosphorous and nitrogen promote its development. *Erwinia* is a ubiquitous bacterium in the natural environment.

Erwinia chrysanthemumi

Erwinia chrysanthemumi attacks a wide range of floral crops including all foliage crops, chrysanthemum, poinsettia and begonia. Its symptoms include root rots, leaf blights and wilts.

Ralstonia solanacearum

Ralstonia solanacearum is a bacterial plant pathogen that causes bacterial wilt. It has a very wide host range. Known previously as *Pseudomonas*, the bacterium is not really a new disease. Because of its diversity, it has been classified into various groupings known as Races and Biovars based on the host range and biochemical reactions. Recently, Race 3 biovar 2, known as the "potato race" has been found on vegetative geranium cuttings originating from tropical or sub-tropical regions. It is of special concern because it has been shown to survive in soil in temperate climatic regions. *Ralstonia solanacearum* Race 3 Biovar 2 is a regulated, quarantinable pathogen in Canada and the U.S. It has also been placed on the USDA's *Agricultural Bioterrorism Act* of 2002 Select Agents and Toxins list. It is a regulated disease because it is not known to exist in North America and because its host range includes two important food crops, potato and tomato.

Growers who suspect the disease must notify the Canadian Food Inspection Agency.

Ralstonia enters plants through the roots and through stem wounds. Race 3 is most severe between 24–35°C and decreases in virulence at very high or very cool temperatures.

Early symptoms are similar to bacterial blight. Lower leaves typically wilt first; sectorial leaf yellowing may be present and stems may show brown to black discolouration near the soil line. Eventually, the entire plant wilts and dies.

The bacterium will survive for long periods of time in soil without plant residue. Under greenhouse conditions the bacterium can be spread on cutting knives, in soil or in contaminated recirculating sub-irrigation systems.

It is thought the disease is easily spread via recirculating systems where pasteurization of the solution is not carried out. The bacteria are spread by splashing water, plant-to-plant contact, infected tools and from contaminated clothing and hands of employees.

For the latest CFIA policy directives and disease factsheet regarding *Ralstonia*, go to the CFIA website at *www.inspection.gc.ca/english/plaveg/pestrava/ralsol/ralstoniae.shtml* or contact your regional CFIA Inspection office.

Controlling this disease consists of quarantine and crop destruction.

Xanthomonas campestris pv.

Xanthomonas campestris and its various strains cause leaf spots and stem rots on a wide range of plants including begonia, geranium, zinnia and dieffenbachia. Symptoms range from small, well-defined spots with yellow margins on leaves to systemic activity where leaf veins become grey-green.

Infected leaves wilt and eventually turn yellow and die. Stems turn dark green as the vascular tissue becomes blocked by the bacteria. In geranium and begonia, distinctive yellow V-shaped areas bounded by major veins usually appear in many leaves. Initially, one branch of the plant may exhibit the symptoms.

Some hosts show no clear symptoms but may not appear very vigorous.

Xanthomonas campestris pv pelargonii commonly known as bacterial blight is very destructive in geranium. It infects all cultivars of zonal, ivy, seed and Martha Washington types. It is a systemic disease that can quickly kill zonal and seed geraniums. Other types are usually not killed but grow poorly and have a "ratty, unthrifty" appearance.

Viral Diseases

Viruses are disease-causing agents that multiply only within living plant cells. They tend to spread throughout the host plant through the vascular system. Many of the important horticultural crops belong to major plant families that are susceptible to viral attack.

With the introduction of many new vegetative annuals to the bedding plant industry, viruses have become of greater importance particularly for those growers who also grow vegetable transplants. Viruses can be spread by sucking insects, such as aphids and leafhoppers, by tools or by crop handling such as plant cleaning, disbudding or taking cuttings. Some viruses spread via infected cuttings.

The first viral infection symptoms may include vein banding, flecking, ring spots, mosaic (irregular areas of dark and light green on the leaf) or growth abnormalities in the leaves. The specific symptoms depend on the type of virus. Symptoms do not always increase in severity. Some viruses cause stunting. In severely infected plants, the growing point of the plant may die.

The extent of the visible symptoms depends on the duration of the infection, the age of the plant at the time of infection and the growing conditions for the crop.

Disease Control

No chemical controls will eradicate viral diseases. Prevention is the key. Good cultural practices and careful sterilization procedures reduce the chance of viral infection.

Purchase disease-free stock from the plant breeder for propagation purposes. Isolate stock plants in a thoroughly disinfected area or screen vents and doors to prevent insect entry. Disinfect cutting tools and propagation areas frequently.

Crop stress predisposes plants to a virus attack. Symptoms will be more apparent in stressed plants.

Tomato Spotted Wilt Virus/Impatiens Necrotic Spot Virus

Tomato spotted wilt virus (TSWV) and impatiens necrotic spot virus (INSV) are very unusual among plant viruses. They are complex particles spread by a few thrips species and they have a broad host range. INSV is the most common; TSWV usually affects only chrysanthemum among floral crops.

In Ontario greenhouse production, TSWV and INSV are transmitted only by western flower thrips. Unlike other insect vectors, thrips must feed on infected plant tissue as first instar larvae to acquire the virus. Virus transmission occurs when infective adults feed and continues for as long as the thrips are alive.

Characteristic symptoms vary depending on the host species and age. For many hosts, large brown or black circular concentric ring spots appear on the foliage. In many hosts, the virus becomes systemic, with black streaking of the major leaf veins, petioles and (in some plants) the stem.

In cyclamen, 8–10 weeks may pass between transmission and the first symptoms. Symptoms generally appear more quickly when plants are growing vigorously. When young gloxinias are infected, the virus rapidly develops systemically. Symptoms appear similar to *Phytophthora* crown rot. In other crops, such as petunia, the viral symptoms appear as small, discrete, tan-coloured spots. In petunia, the infection does not become systemic and this plant can be used as an early warning indicator of the disease.

Sometimes the symptoms mimic pesticide phytotoxicity.

Disease Control

To control disease:

- A simultaneous, multi-pronged approach is necessary for successful control.
- It is very difficult to control the virus during warm weather.
- Rogue virus-infected plants, stock plants and finishing plants to prevent first instar larvae from acquiring the virus.
- Control thrips populations to prevent viral spread. See Chapter 4, *Major Insect and Mite Pests*, on page 47 for detailed information on the life cycle of Western flower thrips.
- Purchase only clean cuttings from reputable propagators.
- Isolate stock plants in a thrips-free area.
- Screen vents.
- Weed control is important—many weeds are reservoirs of the virus and the thrips.

8. Pesticide Toxicity and Activity

The LD_{50} of a pesticide listed in Table 8–2. *Insecticide and Miticide Toxicity and Classification*, Table 8–3. *Fungicide Toxicity and Classification* and Table 8–4. *Growth Regulator Toxicity and Classification* is a measure of its relative toxicity. This is the amount of the active ingredient (a.i.) of the chemical in milligrams used per kilogram of test animal (usually female rats) that kills 50% of the test animals. This is commonly measured as the acute oral LD_{50}, which refers to the chemical ingested through the mouth or nose. Dermal LD_{50} figures, or skin penetration, are also available. The higher the LD_{50} figure, the less toxic the product is to humans.

Note: Many pesticides of low acute toxicity cause long-term effects in laboratory animals. Users are therefore warned that these could be detrimental to human health. Reduce exposure to a minimum by wearing appropriate protective clothing, as outlined in Chapter 1. *Precautions with Pesticides*.

The Ontario Schedule Number referred to in Tables 8–2, 8–3 and 8–4 is a classification under Ontario's *Pesticide Act*, which is administered by the Ministry of Environment. The act prohibits the sale and use of a pesticide product unless it is registered under the federal *Pest Control Products Act* and classified into one of six schedules. See Chapter 1, *Precautions with Pesticides*, on page 1 for more information on this classification system.

Inclusion of a product in these tables does not necessarily imply registration for greenhouse use or registration for a specific crop. Read every product label to ensure suitability for a particular crop!

TABLE 8–1. Fungicidal Activity against Diseases of Flower Crops

	Disease									
Fungicide	*Botrytis*	*Fusarium*	Leaf Spot[1]	Powdery Mildew	Rusts	*Pythium*	*Phytophthora*	*Rhizoctonia*	*Sclerotinia*	*Thielaviopsis*
Aliette (fosetyl-Al)						X	X			
Botran (dicloran)	X									
SupraCaptan, Maestro (captan)	X		X			R				
Compass (trifloxystrobin)								X		
Daconil 2787 (chlorothalonil)	X	X	X	X	X			X		
Decree (fenhexamid)	X									
Folpan (folpet)						X	X			
Meltatox (dodemorph acetate)				X						
Milstop (potassium bicarbonate)				X						
Mycostop (*Streptomyces griseoviridis*)		X				X	X			
No Damp (oxine benzoate)								X		
Nova (myclobutanil)				X	X					
Phyton 27 (elemental copper)	X		X	X						
Quintozene (quintozene)								X	X	

[1] Check label for specific leaf spot control. X Denotes control R Denotes resistance

TABLE 8–1. Fungicidal Activity against Diseases of Flower Crops (cont'd)

	Disease									
Fungicide	*Botrytis*	*Fusarium*	Leaf Spot[1]	Powdery Mildew	Rusts	*Pythium*	*Phytophthora*	*Rhizoctonia*	*Sclerotinia*	*Thielaviopsis*
RootShield (*Trichoderma harzianum*)		X				X		X		
Rovral (iprodione)	X							X	X	
Senator (thiophanate-methyl)	R	R	X	R				X	X	X
Subdue Maxx (metalaxyl)						X	X			
Sulphur			X	X						
Truban (etridiazole)						X	X			

[1] Check label for specific leaf spot control.   X Denotes control   R Denotes resistance

TABLE 8–2. Insecticide and Miticide Toxicity and Classification

Common Name	Trade Name	LD_{50} (mg a.i./kg)	Chemical Family	Ontario Schedule Number
Abamectin	Avid	300	Avermectin	3
Acephate	Orthene	866	Organophosphate	2
Acetamiprid	Tristar	1064	Nicotinoid	2
Bacillus thuringiensis	Dipel, Thuricide, Vectobac, BioProtec	15,000+	Biological	3 2
Bendiocarb	Trumpet	179	Carbamate	2
Bifenazate	Floramite	>5,000	Unclassified acaricide	3
Carbaryl	Sevin	560	Carbamate	3
Chlorpyrifos	Dursban 2E, Dursban WSP, Pyrate	135	Organophosphate	3 2
Clofentezine	Apollo SC	>5,000	Tetrazine	2
Cyromazine	Citation	3,387	Triazine	2
Deltamethrin	Decis	535	Synthetic Pyrethroid	2
Diazinon	Diazinon	300	Organophosphate	2
Dichlorvos	DDVP Smoke 20%EC	80	Organophosphate	3 2
Dicofol	Kelthane	684	Organochlorine	2
Diflubenzuron	Dimilin	4,640	Substituted Benzoylurea	2
Dimethoate	Cygon, Lagon	235	Organophosphate	2
Endosulfan	Thiodan	110	Organochlorine	2
Imidacloprid	Intercept	1,858	Nicotinoid	5
Kinoprene-S	Enstar II	4,900	Insect Growth Regulator	3
Malathion	Malathion	1,400	Organophosphate	3
Mineral oil	Landscape Oil	>15,000		6
Naled	Dibrom	430	Organophosphate	2
Nicotine	Nicotine Smoke	50	Botanical	2

TABLE 8–2. Insecticide and Miticide Toxicity and Classification (cont'd)

Common Name	**Trade Name**	**LD$_{50}$ (mg a.i./kg)**	**Chemical Family**	**Ontario Schedule Number**
Permethrin	Pounce	4,000+	Synthetic Pyrethroid	3
Phosmet	Imidan	126–681	Organophosphate	3
Pirimicarb	Pirliss	147	Carbamate	2
Pymetrozine	Endeavor	>5,000	Pyridine azomethine	2
Pyridaben	Dyno-Mite	1,930	Pyridazinone	3
Spinosad	Success	>5,000	Spinosyn	3
Tebufenozide	Confirm	>5,000	Insect Growth Regulator	2

TABLE 8–3. Fungicide Toxicity and Classification

Common Name	**Trade Name**	**LD$_{50}$ (mg a.i./kg)**	**Chemical Family**	**Ontario Schedule Number**
Azoxystrobin	Heritage	>5,000	Strobilurin	2
Bromine	Agribrom	1,390	Inorganic	3
Captan	SupraCaptan, Maestro	9,000	Phthalimide	2
Chlorothalonil	Daconil 2787	10,000+	Aromatic hydrocarbon	3
Copper	Phyton-27	5,000+	Copper	3
Dazomet	Basamid, Mylone	519	Diazine	3
Dicloran	Botran	10,000+	Dicarboximide	3
Dodemorph acetate	Meltatox	4,180	Morphactin	3
Etridiazole	Truban	1,077	Thiadiazole	3
Fenhexamid	Decree	5,000+	Anilide	2
Folpet	Folpan	10,000+	Phthalimide	2
Fosetyl-Al	Aliette	5,000	Organophosphorus	2
Iprodione	Rovral	3,500	Dicarboximide	3
Mancozeb	Dithane M-45	>5,000	Dithiocarbamate	3
Metalaxyl	Subdue 2G	669	Acylalanine	2
Myclobutanil	Nova	1,870	Triazole	2
Oxine benzoate	No-Damp	1,000+	Aromatic hydrocarbon	3
Potassium bicarbonate	Milstop	2700		3
Quintozene	Quintozene	30,000	Aromatic hydrocarbon	3
Streptomyces griseoviridis	Mycostop	>15,000	Biological	3
Thiophanate methyl	Senator	>6,000	Benzimidazole	3
Trichoderma harzianum	RootShield	Non toxic	Biological	3
Trifloxystrobin	Compass	>5,050	Strobilurin	2
Triforine	Funginex	>5,273	Amide	6
Zineb	Zineb	>5,200	Dithiocarbamate	3

TABLE 8-4. Growth Regulator Toxicity and Classification

Growth Regulator				
Common Name	**Trade Name**	**LD_{50} (mg a.i./kg)**	**Chemical Family**	**Ontario Schedule Number**
Ancymidol	A-Rest	40	Pyrimidine	6
Benzyladenine, G. A_4A_7	Fascination	3,160–4,900	Cytokinin	3
Chlormequat	Cycocel, Cycocel Extra	478	Quaternary Ammonium	2
Daminozide	B-Nine, Dazide	6,810	Organic Acid	2
Paclobutrazol	Bonzi	5,000+	Triazole	2
Uniconazole	Sumagic	1,790	Triazole	2

Pesticide Injury (phytotoxicity) to Flower Crops

Although greenhouse pesticides have been selected and formulated to avoid plant injury, damage can still occur under some conditions. Consider these general rules before you apply pesticides:

- No product is safe on all plants under all conditions, although wettable powders are generally less injurious than liquid formulations.

- A material (e.g. smokes) may be safe when applied to dry foliage but can cause injury when used on wet foliage.

- Weather conditions at the time of application are important. Pesticides are more likely to be phytotoxic when applied during bright sunny weather than if applied during dull, overcast conditions.

- Well-watered, unstressed plants are less likely to be damaged by pesticides.

- Low-volume applications are generally less likely to cause plant injury than high-volume applications.

Pesticide Hazards

The following list of possible hazards was compiled from grower experiences and pesticide label warnings.

This list is not comprehensive. When using a product for the first time on a new crop, always test it first on several different varieties and on a small area and check for damage after four or five days.

- **Avid** may damage Shasta daisy and certain species of fern.

- Do not tank-mix **Botran** with EC formulations of insecticides, particularly organophosphates.

- Do not use **Chlorpyrifos (Pyrate)** on azalea, camellia, poinsettia, rose, geranium, oxalis, coleus or variegated ivy. **Dursban WSP** should not be used on acalyphis, aphelandra, schefflera, croton, ficus, hibiscus, impatiens, nephrolepsis, petunia or rose.

- **D.C.D.** has been reported to cause damage to some greenhouse vegetable crops.

- **DDVP (dichlorvos)** is injurious to some older chrysanthemum varieties (e.g., Shasta and Pink Champagne) and some varieties of snapdragon. Crop should be dry when applied.

- **Dibrom** injures some ornamentals, including some rose varieties, and can damage tradescantia. Avoid over-treatment and direct application to plants.

- **Dimilin** should not be used on poinsettia, hibiscus or Rieger begonia.

- **Dyno-Mite** may cause colour change in blossoms of petunia (cv. White Madness).

- **Enstar II** application to some varieties of poinsettia has resulted in bract damage. Use on some varieties of roses can result in delayed damage.

- Do not use **insecticidal soap** on sweet pea, nasturtium or delicate ferns.

- Do not use **Malathion** on fern, petunia, crassula or African violet.

- Do not use **Meltatox** on Tropicana roses or on plants other than roses.

- **Nicotine** may injure tender plants and African violets.

- **Nova** may result in some growth regulation to treated plants.

- **Pirliss** should not be applied to icecap, goldcap and related varieties of chrysanthemum.

- **Rovral** can cause petal scorch on flowers of African violet.

- **Sevin (carbaryl)** should not be used on Boston ivy, Virginia creeper or maidenhair fern.

- **Thiodan (endosulfan)** should not be used on geraniums or Bonnafon chrysanthemums in the greenhouse or on chrysanthemum cuttings within one month of planting.

- Do not apply **Trumpet** to gloxinia.

Agribrom

- Agribrom is registered for use as a water treatment to control algae.

- To be effective, it must be constantly present in the irrigation water at a low level.

- If irrigation water is being recirculated and Agribrom is added every time the water is reused, monitor chloride levels and suspend use if chloride levels are high.

- Treating reservoir water may also elevate chloride levels, so it is advisable to inject Agribrom just as the water is applied to the crop.

- Follow label directions carefully.

Pressure treated lumber

- Wolmanized® lumber is safe for greenhouse use.

- Copper napthanate has caused some crop injury to poinsettia.

- Other wood preservatives should not be used. Check with a Greenhouse Crop Advisor.

9. Using Plant Growth Regulators

Plant growth, especially vegetative growth, can be controlled by a number of cultural and environmental management techniques.

Cultural

Moisture stress — Growing a crop under moisture stress, which can be accomplished by withholding water within the growing substrate as well as maintaining very low relative humidity, will reduce plant growth.

Nutrition — Excess nitrogen fertilization promotes cell expansion and ultimately stem elongation. Controlling phosphorus levels can also help in controlling vegetative growth.

Average day (24-hour) temperature – Raising or lowering the average 24-hour temperature has an impact on plant height. For example, roses and "cool" crops such as anemones, ranunculus, primula and cineraria will remain short when grown at higher temperature, while crops such as chrysanthemums and lilies are generally taller when grown at higher temperatures.

Day/night temperature or DIF — DIF is defined as the day temperature minus the night temperature. The maintenance of a lower day than night temperature (negative DIF) or the provision of a sudden temperature drop during the morning hours beginning with the first light helps control plant height. In addition, raising or lowering the average 24-hour temperature will increase or retard the rate of plant growth.

Light intensity — Higher light intensities generally produce shorter plants in the greenhouse.

Light quality — Removal of end-of-day twilight from the greenhouse through the use of blackout or special shade cloth, which increases the red/far-red light ratio compared to ambient light, provides a technique to produce short plants.

Mechanical stress — Growing plants in an environment with strong air movement or brushing the plants a number of times per day will reduce plant height.

Cold water — The use of cold water applied overhead can have a growth-regulating effect on plants. For Easter lily (cv. Nellie White), it has been shown that plant height increases linearly with water temperature at about 1.5 cm/°C in the range of 2°C–20°C. In this situation, the water was applied two times a week and 100 mL/plant per watering. Be sure to apply water on the meristem (apical point) of the plant rather than on the soil. Some bedding plants also respond positively to this technique.

Chemical

Plant growth regulators (PGRs) have become an important cultural tool in modifying plant development in greenhouse flower crop production during the last three decades. They influence different plant processes, such as stem elongation, branching, rooting, flower induction and vegetative growth. This section focuses on factors to consider in limiting vegetative growth (controlling height) using PGRs.

Factors to Consider

Plant Vigour

Provide plant growth regulators (PGRs) only to vigorously growing plants or to vigorous cultivars. Avoid weaker plants or less vigorous cultivars, as height reduction may be excessive. PGRs impose a stress on plants and healthy, vigorous plants are more likely to tolerate this stress. A dehydrated plant is more susceptible to phytotoxicity from a PGR than is a turgid plant. Apply PGRs only to plants with well-established root systems. For example, A-Rest applied to Easter lilies with poor root development can cause undue loss of bottom leaves.

Cultivar Response

The growth habit of a cultivar determines the PGR concentration and the number of applications required. For example, a tall-growing pot crysanthemum such as the Princess Anne series will generally need a higher concentration of PGRs than shorter cultivars such as Mandalays. The same is true for certain poinsettia lines.

Environment

Plants grown under low temperature and light may require fewer PGR applications than those grown under higher light and temperatures. Adjust concentrations accordingly for winter and summer production especially when using the more active or stronger PGRs such as Bonzi or Sumagic. Do not apply PGRs when temperatures exceed 22°C. If possible, apply during the evening or during periods of low transpiration losses so the PGR can be absorbed by the plant tissue. This is particularly true for contact PGRs such as B-Nine and, to a lesser extent, Cycocel. Bonzi and Sumagic, both systemic PGRs, are quickly absorbed within the plant tissue.

Stage of Plant Growth

PGRs are most effective when applied to young, vigorous plants. A-Rest applied to Easter lilies under 10 cm high may reduce bud count, delay flowering or severely stunt plant growth. However, when applied too late, A-Rest or Sumagic will produce lilies with a palm tree effect or on poinsettia, bracts that are too small. Early application may affect the development of some (bottom) breaks on poinsettia and chrysanthemum. This is most pronounced with high rates and the more effective PGRs.

Apply much lower rates of Bonzi or Sumagic to bedding plant plug seedlings than when applying to established plants in cell packs or baskets.

Dosage and Coverage

For most PGRs, the concentration of the active ingredient (a.i.) in the solution to be applied is critical. For simple conversion on a normalized level (1 or 1,000 ppm a.i.) see Table 9–1, *Dilution Guidelines for PGRs*.

Measure accurately using proper weighing instruments and/or measuring containers. For A-Rest, the recommendation is for drenching and is expressed as total active ingredient (a.i.) per pot. This means that the solution concentration (mg/L or ppm) multiplied by the solution volume to be applied (L/pot) should equal the dosage (mg/pot).

Always read the label. There may be different formulations on the market or the formulation may have changed. Use the material according to the manufacturer's directions. The label may also indicate the need for a spreader sticker.

Store PGRs in a cool, dry, dark place. Do not allow temperatures to drop below 0°C. Shelf life is at least two years. Note that some PGRs may become unstable once mixed with water. To prevent breakdown, mix just before using.

Application Methods

Drench

Some PGRs (e.g., A-Rest, Bonzi, Cycocel, and Sumagic) are systemic within the plant's vascular system. Drenching may distribute the chemical more evenly within the plant and increase control. Application of PGRs by subirrigation has not yet been approved. Concerns involve appropriate rates and the residues remaining on the tables, floors or troughs.

Drench treatment is more precise than spraying but generally requires more labour.

Be sure roots are well developed before applying the chemical. This is critical for an A-Rest drench on Easter lilies.

TABLE 9–1. Dilution Guidelines for PGRs

Product Name	Active Ingredient	Formulation	Spray or Drench Solution	
			1 ppm	1,000 ppm
A-Rest	Ancymidol	0.0264% (0.264 g/L)	3.8 mL/L	
B-Nine	Daminozide	85 SP (850 g/kg)		1.2 g/L
Dazide	Daminozide	85 WSG		1.2 g/L
Bonzi	Paclobutrazol	0.4% (4 g/L)	0.25 mL/L	
Cycocel Extra	Chlormequat	46.0% (460 g/L)		2.2 mL/L
Fascination	Benzyladenine + gibberellins	1.8%/1.8%	0.056 mL/L	
Sumagic	Uniconazole	0.055% (0.55 g/L)	1.8 mL/L	

Be sure plants are not stressed. Injury can occur if plants are even a little dry. It may be wise to water the plants in late afternoon and apply the treatment the following morning. Another benefit of pre-watering is to have a more even distribution of the PGR throughout the substrate in the pot.

The growing medium should be uniformly saturated. Apply adequate amounts of solution to wet the entire root mass. Drench applications of Sumagic and Bonzi are extremely effective. Accuracy is critical.

Pine bark–based mixes will reduce the efficacy of A-Rest, Bonzi and Sumagic.

Spray

Spray application is easier than using a drench but ensuring uniform foliage coverage is critical. Spraying equipment *must* be operating properly.

Plants should be turgid to prevent foliage damage. When applying Cycocel or B-Nine/Dazide, keep foliage dry for 12–24 hours after spraying to prevent washing the chemicals from the leaves.

Most chemicals contain wetting agents. However, a spreader may be necessary to distribute the chemical uniformly on the foliage and to lessen the likelihood of leaf damage. A rate of 10–20 L of spray/100 m^2 will generally give good coverage. For young and small plants, an even smaller volume can be used. To prevent chemical wastage, arrange the plants as closely together as possible without undue crowding.

Keep a separate sprayer for applying PGRs. Clean the sprayer after each application to prevent unnecessary damage from other chemical residues.

Use the recommended spray volume in Table 9–2, *Recommended Application Volumes*, as a guide.

TABLE 9–2. Recommended Application Volumes

Pot diameter (cm)	Volume of solution (mL/pot)	
	Drench	Spray
10	90	3
13	120	6
15	180	10
20	240	17.5
25	300	25

When applied as foliar sprays, PGRs must be absorbed and transported within the plant. The active ingredient must move through the waxy cuticle layer of the leaf or stem and then into the plant tissue. Highly water-soluble PGRs such as B-Nine/Dazide and Cycocel move slowly through the cuticle, while less-soluble PGRs (Sumagic, Bonzi, A-Rest) penetrate very rapidly.

For Cycocel and B-Nine/Dazide, absorption occurs while the foliage remains wet, meaning that they must be applied in the early morning, at the end of the day or under cloudy, humid conditions with lower air movement. For these products, avoid overhead watering for 12–24 hours, so that the active ingredient is not washed off the plant.

A-Rest, Sumagic and Bonzi are absorbed very rapidly (within minutes), with little potential for being washed off after drying.

Number of Applications

While a single drench or spray application is the most economical, a "one-shot" treatment is vulnerable to mistakes. A split application using the lowest recommended rate (usually half of the highest recommended rate) applied twice is a safer alternative. A one to two week interval between applications increases flexibility and reduces the chance of plant damage. It also allows time to monitor plant growth, take weather changes into account and make repeated applications accordingly. Plant shape generally improves with the technique of multiple applications.

Estimating Final Plant Height

Floriculture researchers have found that the final height of chrysanthemum, Easter lily and poinsettia can be predicted using growth charts over time (graphical tracking). Graphical tracking can help determine the effectiveness of a growth retardant and the need for additional applications. Four weeks following the start of short days, chrysanthemum and poinsettia reach approximately half their final height at maturity. Easter lilies will approximately double in height from the time of visible bud. Measuring the plant height from the pot rim at this time and doubling this number provides an estimate of the final height. If the four-week estimated height is too tall, an additional PGR may be warranted. This will reduce growth further and produce a more desirable plant.

Growers should use graphical tracking in an integrated cultural program as a growth-monitoring technique. Graphical tracking programs are commercially available with typical growth curves for these crops.

Directions for Mixing Plant Growth Regulators

Always read the label. Handle the chemicals according to the manufacturer's recommendations and observe all restrictions and precautions.

When mixing chemicals, note that the final volume of a PGR mixture should include the PGR that will be added. First measure the chemical, then add about half the required water to the tank followed by the measured chemical, followed by more water until the desired final volume of the solution is reached. For example, if the label directions read 60 mL B-Nine/Dazide per L, first add 0.5 L of water, then add 60 mL of B-Nine/Dazide to a suitable measuring container, before adding more water to the 1 L mark. Remember that the final solution, including B-Nine, should be 1 L. Agitate well before and during spraying.

Don't add wetting agent (spreader) if the label states that this is already present in the solution. However, if excessive beading occurs, add wetting agent to eliminate the beading.

Read the label to see if the material is sufficiently stable for storage after mixing. It is best to mix plant growth regulator products right before each application to ensure proper chemical activity.

Don't mix PGRs with any other pesticides. Growth-regulator applications are too critical; don't take chances to save time. Mix and apply PGRs precisely.

Growth Regulator Recommendations for Flower Crops

The efficacy of PGRs can be very crop dependent. Read the label before applying any PGR. See Table 9–3, *Summary of PGRs by Crop* and Table 9–4, *Plant Growth Regulators.*

TABLE 9–3. Summary of PGRs by Crop

Crop	Registered PGRs
Azalea	B-Nine/Dazide
Bedding plants	B-Nine/Dazide, Bonzi, Sumagic
Chrysanthemum (pot)	A-Rest, B-Nine/Dazide, Sumagic
Chrysanthemum (cut)	B-Nine/Dazide
Geranium (zonal)	Bonzi, Cycocel Extra, Sumagic
Hydrangea	B-Nine/Dazide
Easter lilies	A-Rest, Fascination, Sumagic
Lily hybrids	A-Rest, Fascination
Poinsettia	A-Rest, B-Nine/Dazide, Cycocel Extra, Sumagic

TABLE 9–4. Plant Growth Regulators

A-Rest (0.0264% ancymidol)	
Crops	**Chrysanthemum (potted), lily, poinsettia**
Concentration of Active Ingredient	2–8 ppm
Mixing Rate	2 ppm = 7.5 mL per L water 8 ppm = 30 mL per L water
Method of Application	Drench. Apply 0.25 mg active ingredient per 15-cm pot.
Timing	• *Chrysanthemum*: Apply just as root system spreads over outside of root ball, or approximately 2 weeks after pinch when laterals are 5 cm long. • *Lily*: Apply when lily is 7–15 cm tall. Do not apply between Jan. 23 and Feb. 7, as bud count may be reduced. • *Poinsettia*: Treat plants from pinch to 4 weeks after pinch, or 8–12 weeks before finish.
Comments	Entire soil must receive uniform application. Do not apply a wetting agent. Ensure healthy roots and adequate phosphorus nutrition of Easter lily to minimize lower leaf yellowing.

Cycocel Extra (46.0% chlormequat)	
Crops	**Geranium (zonal), poinsettia**
Concentration of Active Ingredient	*Geranium*: 1,500–3,000 ppm *Poinsettia*: 1,500–3,000 ppm
Mixing Rate	1,500 ppm = 3.25 mL per L water 3,000 ppm = 6.5 mL per L water
Method of Application	Drench
Timing	• *Geranium (zonal)*: Apply as a drench at 1,500–3,000 ppm 3 weeks after transplanting, when well-rooted and stem begins to elongate. • *Poinsettia*: Apply when shoots are 2–4 cm tall.
Comments	• *Geranium (zonal)*: Induces earlier flowering and promotes branching. • *Poinsettia*: Application later than Oct. 15 for poinsettias, grown under natural photoperiod, may delay flower development and reduce bract size. Spraying twice with half the recommended concentration is more effective than once at the high concentration.

B-Nine SP/Dazide 85 WSG (85% daminozide)	
Crops	**Azalea, bedding plants, chrysanthemum (potted and cut), hydrangea, poinsettia**
Concentration of Active Ingredient	*Azalea* (1,500–2,500 ppm) *Bedding plants* (5,000 ppm) *Chrysanthemum* *pots* (2,500–5,000 ppm); *cuts* (2,500 ppm) *Hydrangea* (5,000 ppm) *Poinsettia* (5,000–7,500 ppm)
Mixing Rate	2,500 ppm = 3.0 g/L water
Method of Application	Spray (2L/100 m^2)
Timing	• *Azalea*: Apply after last pinch when shoots are 2.5 cm long to promote development of additional buds (1 application at 2,500 ppm or 2 applications at 1,500 ppm – 1 week apart). • *Bedding plants*: Apply 2–3 weeks after transplanting or when the plants begin to elongate. Repeat as required. • *Chrysanthemum (pots)*: Apply when shoots are 2–4 cm long. May be repeated 3 weeks later; *(cuts)*: to prevent stretching of the peduncles, spray 2 days after disbudding or 4 weeks after shade initiation. • *Hydrangea*: Apply first spray between 2 and 3 weeks (4–5 leaf stage), second spray one week later. • *Poinsettia*: Spray when shoots are approximately 5 cm tall. Spray concentration depends on pinching date (which depends on pot size). Vigorous plants may need a second application.
Comments	• *Azalea*: Increases short-day response and early bud formation. Do not let solution drip onto growing medium. • *Bedding plants*: Good for most bedding plants but ineffective on snapdragon, celosia, coleus, pansy, geranium, carnation, cleome, convolvulus and gomphrena. • *Chrysanthemum (pots)*: Use low concentration on pinched crops, high concentration on single-stem plants. Spray foliage to run off; *(cuts)*: do not mix B-Nine with any other pesticides. • *Hydrangea*: Apply after buds are visible if necessary. • *Poinsettia*: Do not add any wetting agent. Late application will delay blooming.

TABLE 9–4. Plant Growth Regulators (cont'd)

Bonzi (0.4% paclobutrazol)

Crops	**Bedding plants in plug trays, cell packs, or small pots**
Concentration of Active Ingredient	0.5–60 ppm depending on method of application and crop species. *Read the label carefully. Bonzi is extremely active at very low concentrations. Test with lower concentrations on all species and cultivars.*
Mixing Rate	1 ppm = 0.25 mL per L water 2 ppm = 0.5 mL per L water 10 ppm = 2.5 mL per L water
Method of Application	Spray (use 1–2 L per 10 m^2 depending on the stage of plant growth) Drench (use 60–80 mL per 10-cm pot; 120–140 mL per 15-cm pot)
Timing	For bedding plants, make first application at the first- or second-leaf stage. Apply to plants in cell packs or pots once plants are established after transplanting, usually 2–3 weeks later.
Comments	• Desired height control is usually obtained with a single spray or drench application but good height control can also be obtained by repeated applications 7–10 days apart at half the recommended concentration. • Take care not to apply excessive amounts of spray to young plants that have not completely covered the medium; excess may enter the medium and act as a drench, resulting in excessive stunting of sensitive species. • Bonzi spray applications are absorbed through the stems, so thorough and uniform coverage is essential. Over-application can result in stunting and delayed flowering.

Fascination (1.8% benzyladenine, BA, and 1.8% gibberellins, GA_{4+7})

Crops	**Easter lily, asiatic hybrid lily and oriental hybrid lily**
Concentration of Active Ingredient	25–100 ppm of benzyladenine or GA_{4+7}
Mixing Rate	25 ppm = 1.4 mL per L water 100 ppm = 5.6 mL per L water
Method of Application	Direct spray at 25 ppm to the lower leaves only at visible bud stage, before leaf yellowing starts. Apply to entire plant at 100 ppm when buds are fully formed and are about to be placed in cold storage. Use standard equipment at low pressure to avoid mists on immature leaves, which will cause stretching of plants. Apply 1.9 L of spray solution to 10 m^2 of bench area and ensure proper coverage of lower leaves but no more than 15 mL per plant, as soil application can also cause stretch. The product is not systemic within the plant, so only leaves contacted will be protected.
Timing	Apply at visible bud stage or just prior to cold storage.
Comments	Differences in plant response due to differences in plant surfaces, leaf orientation and plant structure are possible. Apply during morning or late afternoon, when plants are not under stress.

TABLE 9–4. Plant Growth Regulators (cont'd)

Sumagic (0.055% uniconazole-P)	
Crops	**Bedding plants, chrysanthemum, Easter lily, geranium (seed and zonal), poinsettia**
Concentration of Active Ingredient	*Bedding plants*: 1–30 ppm *Chrysanthemum*: 5–10 ppm *Easter lily*: 3–30 ppm *Geranium*: 2–4 ppm (seed); 2–8 ppm (zonal) *Poinsettia*: 2–8 ppm
Mixing Rate	1 ppm = 1.8 mL per L water 2 ppm = 3.6 mL per L water 10 ppm = 18 mL per L water
Method of Application	Spray (use 1–2 L per 10 m^2 depending on the stage of plant growth) Low pressure and larger droplet size are recommended for best results.
Timing	• *Bedding plants*: Varies depending on the species being treated. Read the label carefully. First application is usually made when seedlings are 2.5–3.0 cm tall. • *Chrysanthemum*: Apply 7–14 days after pinch when the length of the breaks is 3.8–5.0 cm. A single repeat spray can be made 7–21 days after the first, to increase the level of growth reduction. • *Easter lily*: Apply when shoots are 7.5 cm tall. Do not make repeated applications within 2 weeks and avoid late applications. • *Geranium*: *(seed)* apply when plant height is 5–16 cm; *(zonal)* apply to cuttings once rooting is established. • *Poinsettia*: Apply when breaks are 3.5–5.0 cm long (about 10–14 days after pinching). Up to two repeat applications can be made at 7-day intervals until desired growth characteristics are achieved. Do not apply after bracts are initiated.
Comments	• Plant response to Sumagic is strongly influenced by cultural and environmental factors such as growing media, water/fertilizer management, temperature, light, growing house composition and other cultural practices. Treat a limited number of plants at the lowest recommended rate when using for the first time. Lower rates may be needed at lower temperatures. • *Bedding plants:* Use the lowest recommended rate. Check the response of each species first. • *Chrysanthemum:* Two applications may have more effect than the same amount of product applied as a single treatment. • *Easter lily:* Treatment with Sumagic may reduce the water requirement of Easter lily. Avoid late-season applications. Under Ontario conditions, the rate of 2–3 ppm seems suitable with a maximum of three sprays per season. • *Poinsettia:* Bract size and diameter may be slightly reduced with treatment, and days to flowering may be delayed if applied after the initiation of short days.

10. Pest and Disease Control in Greenhouses

This chapter consists of two tables, both of which list pesticide recommendations for greenhouse flower crops. Table 10–1. *Pesticide Recommendations — By Pesticide*, summarizes alphabetically the registered pesticides and the crops and pests on which they can be used. Table 10–2. *Pesticide Recommendations — By Crop*, is a detailed alphabetical listing by crop of pesticide recommendations. For each crop there is a listing of pests and diseases, the control products that are registered and the recommended rates. Always confirm uses and rates on the label before using. The order in which products appear in the tables below does not constitute a preference ranking, although more recently registered products are usually listed nearer to the top. Many pesticides can cause phytotoxic reactions under certain conditions. Read the label carefully and refer to the section on *Pesticide Injury to Flower Crops*, on page 94.

TABLE 10–1. Pesticide Recommendations — By Pesticide

Insecticides

Trade Name (active ingredient)	Pests	Crops
Avid (abamectin)	Spider mites, leafminers	Greenhouse ornamentals
Citation (cyromazine)	Leafminer, fungus gnats, shoreflies	Greenhouse ornamentals
Confirm (tebufenozide)	Armyworms, cutworms, cabbage loopers, tobacco budworm, leafrollers	Greenhouse ornamentals
Dibrom (naled)	Whiteflies, aphids, spider mites, leafrollers, mealybugs	Rose, cut flowers
Dimilin (diflubenzuron)	Fungus gnats, shoreflies	Greenhouse ornamentals
Dipel (*Bacillus thuringiensis*)	Leafrollers, cabbage looper	Rose, chrysanthemum
DDVP smoke fumigator (dichlorvos)	Aphids, spider mites, western flower thrips, whiteflies, mealybugs	Greenhouse ornamentals
DDVP 20% EC (dichlorvos)	Aphids, whiteflies	Greenhouse ornamentals
Decis (deltamethrin)	Western flower thrips	Greenhouse floriculture crops (chrysanthemum, cineraria, Easter lily, geranium)
Dursban WSP, Dursban 2E, Pyrate (chlorpyrifos)	Thrips, whiteflies, scale, mealybugs, leafhoppers	Greenhouse ornamentals
Dyno-Mite (pyridaben)	Whiteflies, spider mites	Greenhouse ornamentals
Endeavor (pymetrozine)	Aphid control, whitefly suppression	Greenhouse ornamentals
Enstar II (kinoprene)	Whiteflies, aphids	Greenhouse ornamentals
Floramite SC (bifenazate)	Two-spotted spider mite, Lewis mite	Greenhouse ornamentals
Insecticidal soap	Aphids, whiteflies, spider mites, mealybugs, soft brown scale	Greenhouse ornamentals
Intercept (imidacloprid)	Aphids, whiteflies	Greenhouse ornamentals
Kelthane (dicofol)	Mites	Greenhouse ornamentals
Malathion (malathion)	Aphids, whiteflies, thrips, mealybugs, spider mites	Chrysanthemum, carnation, rose, geranium, snapdragon
Nicotine (nicotine)	Aphids, thrips, rose midge, chrysanthemum midge	Greenhouse ornamentals
Orthene (acephate)	Aphids, thrips, whitefly, rose midge, leafroller	Greenhouse rose
Pirliss (pirimicarb)	Aphids	Greenhouse ornamentals

TABLE 10–1. Pesticide Recommendations — By Pesticide (cont'd)

Insecticides

Trade Name (active ingredient)	Pests	Crops
Pounce (permethrin)	Whitefly, chrysanthemum leafminer	Greenhouse ornamentals
Success 480 SC (spinosad)	Western flower thrips	Greenhouse ornamentals
Thiodan 50WP, 4EC; Endosulfan 50W, Thionex EC (endosulfan)	Aphids, whitefly, cyclamen mite	Greenhouse ornamentals
Tristar 70 WSP (acetamiprid)	Aphids, leafhoppers, whiteflies	Greenhouse ornamentals
Trumpet (bendiocarb)	Scales, thrips, mealybug, aphids, fungus gnats	Greenhouse ornamentals
Vectobac (*Bacillus thuringiensis*)	Fungus gnats	Greenhouse ornamentals

Fungicides

Trade Name (active ingredient)	Diseases	Crops
Aliette (fosetyl-Al)	*Pythium, Phytophthora*	Greenhouse ornamentals
Botran (dicloran)	*Botrytis*	Rose, geranium, chrysanthemum
Compass 50 WG (trifloxystrobin)	*Rhizoctonia*	Greenhouse ornamentals according to label
Daconil 2787 (chlorothalonil)	Various foliar diseases (see label)	Various bulb, flowering and foliage plants (see label)
Decree (fenhexamid)	*Botrytis*	Greenhouse ornamentals
Folpan (folpet)	*Pythium* root rot	Poinsettia
Maestro, SupraCaptan (captan)	Damping-off, root rots, leaf spots (see label)	Greenhouse rose, other flowers
Meltatox (dodemorph acetate)	Powdery mildew	Rose
Milstop (potassium bicarbonate)	Powdery mildew	Various greenhouse ornamentals (see label)
Mycostop (*Streptomyces griseoviridis*)	*Fusarium, Pythium, Phytophthora*	Greenhouse ornamentals
No-Damp (oxine benzoate)	Damping-off	Ornamental seedlings and cuttings
Nova (myclobutanil)	Rusts, powdery mildew	Geranium, poinsettia, rose, gerbera, aster, chrysanthemum
Phyton 27 (elemental copper)	Various fungal and bacterial foliar diseases (see label)	Various crops as foliar spray, cutting dip and postharvest application (see label)
Quintozene (quintozene)	*Rhizoctonia, Sclerotinia*	Various ornamental and bulb crops (see label)
Rootshield (*Trichoderma harzianum*)	Root diseases caused by *Rhizoctonia, Pythium* and *Fusarium*	Greenhouse ornamentals
Rovral (iprodione)	*Botrytis*, damping-off *(Rhizoctonia)*	Ornamentals
Senator (thiophanate-methyl)	*Rhizoctonia, Fusarium*, powdery mildew, *Botrytis*, leaf spots	Greenhouse potted ornamentals
Subdue Maxx, (metalaxyl)	*Pythium, Phytophthora*	Greenhouse ornamentals
Truban (etridiazole)	*Pythium, Phytophthora*	Various bedding, foliage, container and bed-grown ornamentals (see label)

Other Pesticides

Trade Name (active ingredient)	Pest	Crops
Deadline M-Ps (metaldehyde)	Slugs	Ornamentals
Slug-Em (metaldehyde)	Slugs	Ornamentals
Sluggo (ferric phosphate)	Slugs	Outdoor and greenhouse ornamentals, nurseries

TABLE 10–2. Pesticide Recommendations — By Crop

Plant Name	Problem	Recommendation by Trade Name	Rate/1,000 L (exceptions noted)	Remarks
African Violet (*Saintpaulia*)	Aphid	Intercept 60 WP	Read label carefully	
		Tristar 70 WSP	48 g (3 water soluble packs)	
		Endeavor 50 WG	100–200 g	
		Enstar II	250–750 mL	
		Trumpet 80 W	0.75–1.0 kg	
		Thiodan 4 EC	1.25–1.75 L	
		Thiodan 50 WP	1.0–1.5 kg	
		Thionex EC	1.25–1.75 L	
		Endosulfan 50 W	1.0 kg	
		DDVP Smoke Fumigator	1/300 m^3	
		DDVP 20% EC	6 L	
		Insecticidal Soap	20 L	
		Malathion 25 W	2.5–5.0 kg	
	Cyclamen Mite	Kelthane 50 W	525–700 g	
		Thiodan 50 WP	1.0–1.5 kg	
		Thiodan 4 EC	1.25–1.75 L	
		Endosulfan 50 W	1.0 kg	
		Thionex EC	1.25–1.75 L	
	Fungus Gnat	Citation 75 WP	133 g	Drench
		Dimilin 25 WP	18–150 g	Drench or soil surface spray
		Vectobac 600 L	2–8 L	Drench
		Trumpet 80 WP	1.25 kg	Soil surface spray
	Mealybug	DDVP Smoke Fumigator	1/300 m^3	
		Trumpet 80 WP	0.75–1.0 kg	
		Malathion 25 W	2.5–5.0 kg	
		Insecticidal Soap	20 L	
	Shoreflies	Citation 75 WP	133 g	Drench
		Dimilin 25 WP	18–150 g	Drench or soil surface spray
	Thrips	Success 480 SC	50 mL	Max. 3 applications/crop cycle at 7–10 day intervals
	Two-Spotted Spider Mite	Floramite SC	133 mL/400L (333 mL/1000L)	
		Avid 1.9% EC	300 mL	
		Dyno-Mite 75 W	142–284 g (5–10 PVA bags)	
		Kelthane 50 W	525–700 g	
		Insecticidal Soap	20 L	
		Malathion 25 W	2.5–5.0 kg	
		DDVP Smoke Fumigator	1/300 m^3	

TABLE 10–2. Pesticide Recommendations — By Crop (cont'd)

Plant Name	Problem	Recommendation by Trade Name	Rate/1,000 L (exceptions noted)	Remarks
African Violet (cont'd)	*Botrytis*	Decree 50 WDG	1.12 kg	Apply using high-volume or low-volume equipment at 1.12 kg/ha
		Rovral 50% WP	1.0 kg	
		Senator 70 WP	650–850 g	
	Crown Rot *Pythium/Phytophthora*	Subdue Maxx	5 mL/m^3	Soil mix at seeding and transplanting
		Truban 25 EC	300–630 mL	
		RootShield Drench	600–900 g	
		RootShield Granules	600 g/m^3	Soil mix
		Mycostop Biofungicide	Read label carefully	
	Rhizoctonia Stem Rot	Quintozene	1.25 kg	Drench
		Senator 70 WP	650–850 g	Drench
		RootShield Drench	600–900 g	
		RootShield Granules	600 g/m^3	Soil mix
Aster	*Botrytis*	Maestro 75 DF	1.5 kg	
		Supra Captan 80 WDG	1.25 kg	
		Rovral 50% WP	1.0 kg	Trial on a few plants before large-scale application
		Senator 70 WP	650–850 g	
	Powdery Mildew	Nova 40 W	340 g	
Azalea	Aphid	Intercept 60 WP	Read label carefully	
		Tristar 70 WSP	48 g (3 water soluble packs)	
		Endeavor 50 WG	100–200 g	
		Thiodan 4 EC	1.25–1.75 L	
		Thiodan 50 WP	1.0–1.5 kg	
		Thionex EC	1.25–1.75 L	
		Endosulfan 50W	1.0 kg	
		DDVP Smoke Fumigator	1/300 m^3	
		DDVP 20% EC	6 L	
		Trumpet 80 W	0.75–1.0 kg	
		Enstar II	250–750 mL	
		Insecticidal Soap	20 L	
		Malathion 25 W	2.5–5.0 kg	
		Nicotine Smoke Fumigator	1/300 m^3	
	Cyclamen Mite	Kelthane 50 W	525–700 g	
		Thiodan 50 WP	1.0–1.5 kg	
		Thiodan 4 EC	1.25–1.75 L	
		Endosulfan 50 W	1.0 kg	
		Thionex EC	1.25–1.75 L	

TABLE 10–2. Pesticide Recommendations — By Crop (cont'd)

Plant Name	Problem	Recommendation by Trade Name	Rate/1,000 L (exceptions noted)	Remarks
Azalea (cont'd)	Fungus Gnat	Citation 75 WP	133 g	Drench
		Dimilin 25 WP	18–150 g	Drench or soil surface spray
		Vectobac 600 L	2–8 L	Drench
		Trumpet 80 WP	1.25 kg	Soil surface spray
	Leafroller	Confirm 240 F	1.0 L	
	Shoreflies	Citation 75 WP	133 g	Drench
		Dimilin 25 WP	18–150 g	Drench or soil surface spray
	Thrips	Success 480 SC	50 mL	Max. 3 applications/crop cycle at 7–10 day intervals
		Trumpet 80 W	0.75–1.0 kg 1.25 kg	Foliar spray Soil-surface spray
		Malathion 25 W	2.5–5.0 kg	
		DDVP Smoke Fumigator	1/300 m^3	
		Nicotine Smoke Fumigator	1/300 m^3	
	Two-Spotted Spider Mite	Floramite SC	133 mL/400 L (333 mL/1000 L)	
		Dyno-Mite 75 W	142–284 g (5–10 PVA bags)	
		Avid 1.9% EC	300 mL	
		Insecticidal Soap	20 L	
		Kelthane 50 W	525–700 g	
		Malathion 25 W	2.5–5.0 kg	
		DDVP Smoke Fumigator	1/300 m^3	
	Whitefly	Intercept 60 WP	Read label carefully	
		Tristar 70 WSP	80-160 g (5-10 water soluble packs)	
		Dyno-Mite 75 W	284–425 g (10–15 PVA bags)	
		Enstar II	250–750 mL	
		Insecticidal soap	20 L	
		Endeavor 50 WG	200 g	Suppression only
		Thiodan 4 EC	1.25–1.75 L	
		Thiodan 50 WP	1.0–1.5 kg	
		Thionex EC	1.25–1.75 L	
		Endosulfan 50 W	1.0 kg	
		Trumpet 80 W	0.75–1.0 kg	
		DDVP Smoke Fumigator	1/300 m^3	
		DDVP 20% EC	6 L	
		Malathion 25 W	2.5–5.0 kg	
	Cylindrocladium	Phyton 27	1.25–2.75 L	

TABLE 10–2. Pesticide Recommendations — By Crop (cont'd)

Plant Name	Problem	Recommendation by Trade Name	Rate/1,000 L (exceptions noted)	Remarks
Azalea (cont'd)	Damping-off *Pythium/Phytophthora*	Subdue Maxx	5 mL/m^3	Soil mix at seeding and transplanting
		RootShield Drench	600–900 g	
		RootShield Granules	600 g/m^3	Soil mix
		Mycostop Biofungicide	Read label carefully	
	Rhizoctonia	Compass 50WG	38 g	
		Senator 70 WP	650–850 g	Drench
		Maestro 75 DF	3.25–6.5 kg	Cutting dip
		Supra Captan 80 WDG	3.0–6.0 kg	Cutting dip
		RootShield Drench	600–900 g	
		RootShield Granules	600 g/m^3	Soil mix
	Phytophthora	Aliette WDG	2.8 kg	Foliar application
		Subdue Maxx	5 mL/m^3	Soil mix at seeding and transplanting
		RootShield Drench	600–900 g	
		RootShield Granules	600 g/m^3	Soil mix
		Mycostop Biofungicide	Read label carefully	
Bedding Plants	Aphid	Intercept 60 WP	Read label carefully	
		Tristar 70 WSP	48 g (3 water soluble packs)	
		Endeavor 50 WG	100–200 g	
		Enstar II	250–750 mL	
		Pirliss 50 DF	500 g	
		Insecticidal Soap	20 L	
		Trumpet 80 W	0.75–1.0 kg	Due to diversity of types, test a few plants first
		Thiodan 50 WP	1.0–1.5 kg	
		Thiodan 4 EC	1.25–1.75 L	
		Endosulfan 50 W	1.0 kg	
		Thionex EC	1.25–1.75 L	
		Nicotine Smoke Fumigator	1/300 m^3	
		DDVP Smoke Fumigator	1/300 m^3	
		DDVP 20% EC	6 L	
		Malathion 25 W	2.5–5.0 kg	
	Fungus Gnat	Citation 75 WP	133 g	Drench
		Dimilin 25 WP	18–150 g	Drench or soil surface spray
		Vectobac 600 L	2–8 L	Drench
		Trumpet 80 W	1.25 kg	Soil surface spray
	Thrips	Success 480 SC	50 mL	Max. 3 applications/crop cycle at 7–10 day intervals
		Trumpet 80 W	0.75–1.0 kg 1.25 kg	Foliar spray Soil surface spray
		DDVP Smoke Fumigator	1/300 m^3	
		Dursban WSP	448 g (4 water soluble packs)	
		Dursban 2E	1 L	

TABLE 10–2. Pesticide Recommendations — By Crop (cont'd)

Plant Name	Problem	Recommendation by Trade Name	Rate/1,000 L (exceptions noted)	Remarks
Bedding Plants (cont'd)	Thrips (cont'd)	Pyrate 480 EC	500 mL	
		Malathion 25 W	2.5–5.0 kg	
		Nicotine Smoke Fumigator	1/300 m^3	
	Shoreflies	Citation 75 WP	133 g	Drench
		Dimilin 25 WP	18–150 g	Drench or soil surface spray
	Two-Spotted Spider Mite	Floramite SC	133 mL/400 L (333 mL/1000 L)	
		Avid 1.9% EC	300 mL	
		Dyno-Mite 75 W	142–284 g (5–10 PVA bags)	
		Kelthane 50 W	525–700 g	
		DDVP Smoke Fumigator	1/300 m^3	
		Insecticidal Soap	20 L	
		Malathion 25 W	2.5–5.0 kg	
	Whitefly	Intercept 60 WP	Read label carefully	
		Tristar 70 WSP	80-160 g (5-10 water soluble packs)	
		Enstar II	250–750 mL	
		Dyno-Mite 75 W	284–425 g (10–15 PVA bags)	
		Endeavor 50 WG	200 g	Suppression only
		Insecticidal Soap	20 L	
		Trumpet 80 W	0.75-1.0 kg	
		Pounce 384 EC	260 mL	
		Dursban WSP	448g (4 water soluble packs)	
		Dursban 2E	1 L	
		Pyrate 480 EC	500 mL	
		DDVP Smoke Fumigator	1/300 m^3	
		DDVP 20% EC	6 L	
		Thiodan 50 WP	1.0–1.5 kg	
		Thiodan 4 EC	1.25–1.75 L	
		Endosulfan 50 W	1.0 kg	
		Thionex EC	1.25–1.75 L	
		Malathion 25 W	2.5–5.0 kg	
	Botrytis	Decree 50 WDG	1.12 kg	Apply using high-volume or low-volume equipment at 1.12 kg/ha
		Rovral 50% WP	1 kg	
		Senator 70 WP	650–850 g	
		Daconil 2787	2.5 L	Species as listed on label
	Damping-off *Pythium/ Phytophthora*	Truban 30% WP	90–135 g 55–110 g/m^3	Soil drench Dry soil mix
		Truban 25 EC	240–300 mL	
		Subdue Maxx	5 mL/m^3	Soil mix at seeding and transplanting

TABLE 10–2. Pesticide Recommendations — By Crop (cont'd)

Plant Name	Problem	Recommendation by Trade Name	Rate/1,000 L (exceptions noted)	Remarks
Bedding Plants (cont'd)	Damping-off (cont'd)	Aliette WDG	2.8 kg 950 g	Foliar application Drench
		RootShield Drench	600–900 g	
		RootShield Granules	600 g/m^3	Soil mix
		Mycostop Biofungicide	Read label carefully	Drench, but can also be used as a seed treatment
	Rhizoctonia	Compass 50WG	38 g	
		Senator 70 WP	650–850 g	Drench
		Maestro 75 DF	1.5 kg	
		Supra Captan 80 WDG	1.5 kg	
		No-Damp	10 L	
		RootShield Drench	600–900 g	
		RootShield Granules	600 g/m^3	Soil mix
Begonia (Rieger)	Aphid	Intercept 60 WP	Read label carefully	
		Tristar 70 WSP	48 g (3 water soluble packs)	
		Endeavor 50 WG	100–200 g	
		Enstar II	250–750 mL	
		Thiodan 50 WP	1.0–1.5 kg	
		Thiodan 4 EC	1.25–1.75 L	
		Endosulfan 50 W	1.0 kg	
		Thionex EC	1.25–1.75 L	
		DDVP Smoke Fumigator	1/300 m^3	
		DDVP 20% EC	6 L	
		Trumpet 80 W	0.75–1.0 kg	
		Malathion 25 W	2.5–5.0 kg	
		Nicotine Smoke Fumigator	1/300 m^3	
		Insecticidal Soap	20 L	
	Fungus Gnat	Citation 75 WP	133 g	Drench
		Vectobac 600 L	2–8 L	Drench
		Trumpet 80 W	1.25 kg	Soil surface spray
	Mealybug	Malathion 25 W	2.5–5.0 kg	
		DDVP Smoke Fumigator	1/300 m^3	
		Trumpet 80 W	0.75–1.0 kg	
		Dursban WSP	224 g (2 water soluble packs)	
		Pyrate 480 EC	200 mL	
		Insecticidal Soap	20 L	
	Shoreflies	Citation 75 WP	133 g	Drench
	Thrips	Success 480 SC	50 mL	Max. 3 applications/crop cycle at 7–10 day intervals
		Trumpet 80 W	0.75–1.0 kg 1.25 kg	Foliar spray Soil surface spray
		Malathion 25 W	2.5–5.0 kg	
		DDVP Smoke Fumigator	1/300 m^3	

TABLE 10–2. Pesticide Recommendations — By Crop (cont'd)

Plant Name	Problem	Recommendation by Trade Name	Rate/1,000 L (exceptions noted)	Remarks
Begonia (Reiger) (cont'd)	Thrips (cont'd)	Dursban WSP	448 g (4 water soluble packs)	
		Dursban 2E	1 L	
		Pyrate 480 EC	500 mL	
		Nicotine Smoke Fumigator	1/300 m^3	
	Two-Spotted Spider Mite	Floramite SC	133 mL/400 L (333 mL/1000 L)	
		Avid 1.9% EC	300 mL	
		Dyno-Mite 75 W	142–284 g (5–10 PVA bags)	
		Kelthane 50 W	525–700 g	
		Insecticidal Soap	20 L	
		Malathion 25 W	2.5–5.0 kg	
		DDVP Smoke Fumigator	1/300 m^3	
	Whitefly	Intercept 60 WP	Read label carefully	
		Tristar 70 WSP	80-160 g (5-10 water soluble packs)	
		Dyno-Mite 75 W	284–425 g (10-15 PVA bags)	
		Enstar II	250–750 mL	
		Endeavor 50 WG	200 mL	Suppression only
		Trumpet 80 W	0.75–1.0 kg	
		Insecticidal Soap	20 L	
		Thiodan 50 WP	1.0–1.5 kg	
		Thiodan 4 EC	1.25–1.75 L	
		Endosulfan 50 W	1.0 kg	
		Thionex EC	1.25–1.75 L	
		DDVP Smoke Fumigator	1/300 m^3	
		DDVP 20% EC	6 L	
		Dursban WSP	448 g (4 water soluble packs)	
		Dursban 2E	1 L	
		Pyrate 480 EC	500 mL	
		Malathion 25 W	2.5–5.0 kg	
		Pounce 384 EC	260 mL	
	Botrytis	Decree 50 WDG	1.12 kg	Apply using high-volume or low-volume equipment at 1.12 kg/ha
		Rovral 50% WP	1.0 kg	
		Senator 70 WP	650–850 g	
	Root Rot (Cuttings) *Pythium/Phytophthora*	Truban 30% WP	90–135 g 55–110 g	Drench Dry soil mix
		Subdue Maxx	5 mL/m^3	Soil mix at seeding and transplanting
		Aliette WDG	2.8 kg	Foliar application
		RootShield Drench	600–900 g	

TABLE 10–2. Pesticide Recommendations — By Crop (cont'd)

Plant Name	Problem	Recommendation by Trade Name	Rate/1,000 L (exceptions noted)	Remarks
Begonia (Reiger) (cont'd)	Root Rot (Cuttings) (cont'd)	RootShield Granules	600 g/m^3	Soil mix
		Mycostop Biofungicide	Read label carefully	
	Rhizoctonia	Compass 50WG	38 g	
		Senator 70 WP	650–850 g	Drench
		Quintozene	1.25 kg	Drench
		RootShield Drench	600–900 g	
		RootShield Granules	600 g/m^3	Soil mix
		Supra Captan 80 WDG	1.5 kg	
		Maestro 75 DF	1.5 kg	
	Powdery Mildew	Phyton-27	1.25–2.5 L	
Bulb Crops	Tulip Bulb Aphid	Intercept 60 WP	Read label carefully	
		Tristar 70 WSP	48 g (3 water soluble packs)	
		Endeavor 50 WG	100–200 g	
		Enstar II	250–750 mL	
		DDVP Smoke Fumigator	1/300 m^3	
		DDVP 20% EC	6 L	
		Trumpet 80 W	0.75–1.0 kg	
		Thiodan 50 WP	1.0–1.5 kg	
		Thiodan 4 EC	1.25–1.75 L	
		Endosulfan 50 W	1.0 kg	
		Thionex EC	1.25–1.75 L	
		Insecticidal Soap	20 L	
		Malathion 25 W	2.5–5.0 kg	
		Nicotine Smoke Fumigator	1/300 m^3	
		Dibrom Insecticide	10 mL/100 m^3	
	Fungus Gnat	Citation 75 WP	133 g	Drench
		Dimilin 25 WP	18–150 g	Drench or soil surface spray
		Vectobac	2–8 L	Drench
		Trumpet 80 W	1.25 kg	Soil surface spray
	Shoreflies	Citation 75 WP	133 g	Drench
		Dimilin 25 WP	18–150 g	Drench or soil surface spray
	Botrytis	Decree 50 WDG	1.12 kg	Apply using high-volume or low-volume equipment at 1.12 kg/ha
		Supra Captan 80 WDG	1.5 kg	
		Maestro 75 DF	1.5 kg	
		Daconil 2787	2.5 L	
		Rovral 50% WP	1.0 kg	Trial on a few plants before large-scale application
		Senator 70 WP	650–850 g	

TABLE 10–2. Pesticide Recommendations — By Crop (cont'd)

Plant Name	Problem	Recommendation by Trade Name	Rate/1,000 L (exceptions noted)	Remarks
Bulb Crops (cont'd)	Bulb Rot	Quintozene 75 WP	1 kg/10 L	Bulb dip
		Maestro 75 DF	4–10 kg	Bulb dip
		Supra Captan 80 WDG	3.75–9.5 kg	Bulb dip
		RootShield Drench	120 g/L	Bulb dip
Calceolaria	Aphid	Intercept 60 WP	Read label carefully	
		Tristar 70 WSP	48 g (3 water soluble packs)	
		Endeavor 50 WG	100–200 g	
		Enstar II	250–750 mL	
		Insecticidal Soap	20 L	
		Trumpet 80 W	0.75–1.0 kg	
		Thiodan 50 WP	1.0–1.5 kg	
		Thiodan 4 EC	1.25–1.75 L	
		Endosulfan 50 W	1.0 kg	
		Thionex EC	1.25–1.75 L	
		DDVP Smoke Fumigator	1/300 m^3	
		DDVP 20% EC	6 L	
		Malathion 25 W	2.5–5.0 kg	
		Nicotine Smoke Fumigator	1/300 m^3	
	Fungus Gnat	Citation 75 WP	133 g	Drench
		Dimilin 25 WP	18–150 g	Drench or soil surface spray
		Vectobac 600 L	2–8 L	Drench
		Trumpet 80 W	1.25 kg	Soil surface spray
	Shoreflies	Citation 75 WP	133 g	Drench
		Dimilin 25 WP	18–150 g	Drench or soil surface spray
	Two-Spotted Spider Mite	Floramite SC	133 mL/400 L (333 mL/1000 L)	
		Avid 1.9% EC	300 mL	
		Dyno-Mite 75 W	142–284 g (5–10 PVA bags)	
		Insecticidal Soap	20 L	
		Kelthane 50 W	525–700 g	
		DDVP Smoke Fumigator	1/300 m^3	
		Malathion 25 W	2.5–5.0 kg	
	Whitefly	Intercept 60 WP	Read label carefully	
		Tristar 70 WSP	80-160 g (5-10 water soluble packs)	
		Dyno-Mite 75 W	284–425 g (10–15 PVA bags)	
		Enstar II	250–750 mL	
		Endeavor 50 WG	200 g	Suppression only

TABLE 10–2. Pesticide Recommendations — By Crop (cont'd)

Plant Name	Problem	Recommendation by Trade Name	Rate/1,000 L (exceptions noted)	Remarks
Calceolaria (cont'd)	Whitefly (cont'd)	Insecticidal Soap	20 L	
		Trumpet 80 W	0.75–1.0 kg	
		Thiodan 50 WP	1.0–1.5 kg	
		Thiodan 4 EC	1.25–1.75 L	
		Endosulfan 50 W	1.0 kg	
		Thionex EC	1.25–1.75 L	
		DDVP Smoke Fumigator	1/300 m^3	
		DDVP 20% EC	6 L	
		Dursban WSP	448 g (4 water soluble packs)	
		Dursban 2E	1 L	
		Pyrate 480 EC	500 mL	
		Malathion 25 W	2.5–5.0 kg	
	Botrytis	Decree 50 WDG	1.12 kg	Apply using high-volume or low-volume equipment at 1.12 kg/ha
		Rovral 50 WP	1.0 kg	Trial on a few plants before large-scale application
		Senator 70 WP	650–850 g	
Carnation	Aphid	Intercept 60 WP	Read label carefully	
		Tristar 70 WSP	48 g (3 water soluble packs)	
		Endeavor 50 WG	100–200 g	
		Enstar II	250–750 mL	
		Pirliss 50 DF	500 g	
		Insecticidal Soap	20 L	
		Trumpet 80 W	0.75–1.0 kg	
		Nicotine Smoke Fumigator	1/300 m^3	
		DDVP Smoke Fumigator	1/300 m^3	
		DDVP 20% EC	6 L	
		Malathion 50% EC	2.0 L	
		Malathion 25 W	2.5–5.0 kg	
		Dibrom Insecticide	10 mL/100 m^3	
		Thiodan 50 WP	1.0–1.5 kg	
		Thiodan 4 EC	1.25–1.75 L	
		Endosulfan 50 W	1.0 kg	
		Thionex EC	1.25–1.75 L	
	Fungus Gnat	Citation 75 WP	133 g	Drench
		Dimilin 25 WP	18–150 g	Drench or soil surface spray
		Vectobac	2–8 L	Drench
		Trumpet 80 W	1.25 kg	Soil surface spray
	Shoreflies	Citation 75 WP	133 g	Drench
		Dimilin 25 WP	18–150 g	Drench or soil surface spray

TABLE 10–2. Pesticide Recommendations — By Crop (cont'd)

Plant Name	Problem	Recommendation by Trade Name	Rate/1,000 L (exceptions noted)	Remarks
Carnation (cont'd)	Thrips	Success 480 SC	50 mL	Max. 3 applications/crop cycle at 7–10 day intervals
		Trumpet 80 W	0.75–1.0 kg 1.25 kg	Foliar spray Soil surface spray
		Dursban WSP	448 g (4 water soluble packs)	
		Dursban 2E	1 L	
		Pyrate 480 EC	500 mL	
		DDVP Smoke Fumigator	1/300 m^3	
		Malathion 50% EC	2.0 L	
		Malathion 25 W	2.5–5.0 kg	
		Nicotine Smoke Fumigator	1/300 m^3	
	Two-Spotted Spider Mite	Floramite SC	133 mL/400L (333 mL/1000 L)	
		Avid 1.9% EC	300 mL	
		Dyno-Mite 75 W	142–284 g (5–10 PVA bags)	
		Insecticidal Soap	20 L	
		Kelthane 50 W	525–700 g	
		DDVP Smoke Fumigator	1/300 m^3	
		Malathion 50% EC	2.0 L	
		Malathion 25 W	2.5–5.0 kg	
		Dibrom Insecticide	10 mL/100 m^3	
	Alternaria Leaf Spot	Supra Captan 80 WDG	1.25 kg	
		Maestro 75 DF	1.3–1.6 kg	
		Daconil 2787	2.5 L	
		Senator	650–850 g	
	Botrytis	Decree 50 WDG	1.12 kg	Apply using high-volume or low-volume equipment at 1.12 kg/ha
		Daconil 2787	2.5 L	
		Rovral 50 WP	1.0 kg	Trial on a few plants before large-scale application
		Senator 70 WP	650–850 g	
	Rhizoctonia Stem Rot	Compass 50WG	38 g	
		Quintozene 75 WP	1.25 kg	Drench
		Senator 70 WP	650–850 g	Drench
		Supra Captan 80 WDG	3–6 kg	Cutting dip
		Maestro 75 DF	3.25–6.5 kg	Cutting dip
		RootShield Drench	600–900 g	
		RootShield Granules	600 g/m^3	Soil mix
Chrysanthemum	Aphid	Intercept 60 WP	Read label carefully	
		Tristar 70 WSP	48 g (3 water soluble packs)	
		Endeavor 50 WG	100–200 g	
		Enstar II	250–750 mL	
		Insecticidal soap	20 L	

TABLE 10–2. Pesticide Recommendations — By Crop (cont'd)

Plant Name	Problem	Recommendation by Trade Name	Rate/1,000 L (exceptions noted)	Remarks
Chrysanthemum (cont'd)	Aphids (cont'd)	Pirliss DF	500 g	
		Trumpet 80 W	0.75–1.0 kg	
		Nicotine Smoke Fumigator	1/300 m^3	
		DDVP Smoke Fumigator	1/300 m^3	
		DDVP 20% EC	6 L	
		Malathion 50% EC	2.0 L	
		Malathion 25 W	2.5–5.0 kg	
		Dibrom Insecticide	10 mL/100 m^3	
		Thiodan 50 WP	1.0-1.5 kg	
		Thiodan 4 EC	1.25–1.75 L	
		Endosulfan 50 W	1.0 kg	
		Thionex EC	1.25–1.75 L	
	Cabbage Looper	Confirm 240 F	500 mL	
		Dipel DF	312–625 g	
		Dipel WP	0.625–1.25 kg	
		Thuricide HPC	5 L	
		BioProtec CAF	1.8 L	
	Cyclamen Mite	Kelthane 50 W	525–700 g	
		Thiodan 50 WP	1.0–1.5 kg	
		Thiodan 4 EC	1.25–1.75 L	
		Endosulfan 50 W	1.0 kg	
		Thionex EC	1.25–1.75 L	
	Fungus Gnat	Citation 75 WP	133 g	Drench
		Dimilin 25 WP	18–150 g	Drench or soil surface spray
		Vectobac 600 L	2–8 L	Drench
		Trumpet 80 W	1.25 kg	Soil surface spray
	Leafminer	Avid 1.9% EC	600 mL	
		Citation 75 WP	188 g	Can be used in LVMs at 188 g/ha
		Pounce 384 EC	260 mL	
	Shoreflies	Citation 75 WP	133 g	Drench
		Dimilin 25 WP	18–150 g	Drench or soil surface spray
	Thrips	Success 480 SC	50 mL	Max. 3 applications/crop cycle at 7–10 day intervals
		Trumpet 80 W	0.75–1.0 kg 1.25 kg	Foliar spray Soil surface spray
		Dursban WSP	448 g (4 water soluble packs)	
		Dursban 2E	1 L	
		Pyrate 480 EC	500 mL	
		Malathion 50% EC	2.0 L	
		Malathion 25 W	2.5–5.0 kg	
		DDVP Smoke Fumigator	1/300 m^3	

TABLE 10–2. Pesticide Recommendations — By Crop (cont'd)

Plant Name	Problem	Recommendation by Trade Name	Rate/1,000 L (exceptions noted)	Remarks
Chrysanthemum (cont'd)	Thrips (cont'd)	Decis 5.0 EC	0.35–0.5 L	
		Nicotine Smoke Fumigator	1/300 m^3	
	Two-Spotted Spider Mite	Floramite SC	133 mL/400 L (333 mL/1000 L)	
		Avid 1.9% EC	300 mL	
		Dyno-Mite 75 W	142–284 g (5–10 PVA bags)	
		Insecticidal Soap	20 L	
		Kelthane 50 W	525–700 g	
		Malathion 50% EC	2.0 L	
		Malathion 25 W	2.5–5.0 kg	
		DDVP Smoke Fumigator	1/300 m^3	
		Dibrom Insecticide	10 mL/100 m^3	
	Whitefly	Intercept 60 WP	Read label carefully	
		Tristar 70 WSP	80-160 g (5-10 water soluble packs)	
		Dyno-Mite 75 W	284–425 g (10–15 PVA bags)	
		Enstar II	250–750 mL	
		Endeavor 50 WG	200 g	Suppression only
		Insecticidal Soap	20 L	
		Trumpet 80 W	0.75–1.0 kg	
		DDVP Smoke Fumigator	1/300 m^3	
		DDVP 20% EC	6 L	
		Dursban WSP	448 g (4 water soluble packs)	
		Dursban 2E	1 L	
		Pyrate 480 EC	500 mL	
		Thiodan 50 WP	1.0–1.5 kg	
		Thiodan 4 EC	1.25–1.75 L	
		Endosulfan 50 W	1.0 kg	
		Thionex EC	1.25–1.75 L	
		Malathion 50% EC	2.0 L	
		Malathion 25 W	2.5–5.0 kg	
		Dibrom Insecticide	10 mL/100 m^3	
		Pounce 384 EC	260 mL	
	Leaf Spot	Daconil 2787	2.5 L	
		Senator	650–850 g	
		Supra Captan 80 WDG	1.25 kg	
		Maestro 75 DF	1.3–1.6 kg	
	Ascochyta Ray Blight	Daconil 2787	2.5 L	
	Botrytis	Decree 50 WDG	1.12 kg	Apply using high-volume or low-volume equipment at 1.12 kg/ha
		Daconil 2787	2.5 L	
		Maestro 75 DF	1.3–1.6 kg	

TABLE 10–2. Pesticide Recommendations — By Crop (cont'd)

Plant Name	Problem	Recommendation by Trade Name	Rate/1,000 L (exceptions noted)	Remarks
Chrysanthemum (cont'd)	*Botrytis* (cont'd)	Supra Captan 80 WDG	1.25 kg	
		Botran 75% WP	925 g	
		Rovral 50% WP	1.0 kg	
		Senator	650–850 g	
	Root Rot *Pythium*/*Phytophthora*	Truban 30% WP	500–750 g 55–110 g/m^3	Drench Dry soil mix
		Truban 25% EC	300–630 mL	
		Subdue Maxx	5 mL/m^3	Soil mix at seeding and transplanting
		RootShield Drench	600–900 g	
		RootShield Granules	600 g/m^3	Soil mix
		Mycostop Biofungicide	Read label carefully	
	Rhizoctonia	Compass 50WG	38 g	
		Senator	650–850 g	Drench
		Quintozene 75 WP	1.25 kg	Drench
		Supra Captan 80 WDG	1.5 kg 3–6 kg	Soil treatment Cutting dip
		Maestro 75 DF	1.5 kg 3.25–6.5 kg	Soil treatment Cutting dip
		RootShield Drench	600–900 g	
		RootShield Granules	600 g/m^3	Soil mix
	Rust	Nova 40W	340 g	
Cineraria	Aphid	Intercept 60 WP	Read label carefully	
		Tristar 70 WSP	48 g (3 water soluble packs)	
		Endeavor 50 WG	100–200 g	
		Enstar II	250–750 g	
		Trumpet 80 W	0.75–1.0 kg	
		Insecticidal Soap	20 L	
		Thiodan 50 WP	1.0–1.5 kg	
		Thiodan 4 EC	1.25–1.75 L	
		Endosulfan 50 W	1.0 kg	
		Thionex EC	1.25–1.75 L	
		DDVP Smoke Fumigator	1/300 m^3	
		DDVP 20% EC	6 L	
		Malathion 25 W	2.5–5.0 kg	
		Nicotine Smoke Fumigator	1/300 m^3	
	Fungus Gnat	Citation 75 WP	133 g	Drench
		Dimilin 25 WP	18–150 g	Drench or soil surface spray
		Vectobac 600 L	2–8 L	Drench
		Trumpet 80 W	1.25 kg	Soil surface spray
	Shoreflies	Citation 75 WP	133 g	Drench
		Dimilin 25 WP	18–150 g	Drench or soil surface spray

TABLE 10–2. Pesticide Recommendations — By Crop (cont'd)

Plant Name	Problem	Recommendation by Trade Name	Rate/1,000 L (exceptions noted)	Remarks
Cineraria (cont'd)	Thrips	Success 480 SC	50 g	
		Trumpet 80 W	0.75–1.0 kg	Foliar spray
			1.25 kg	Soil surface spray
		Dursban WSP	448 g (4 water soluble packs)	
		Dursban 2E	1 L	
		Pyrate 480 EC	500 mL	
		Malathion 25 W	2.5–5.0 kg	
		Decis 5.0 EC	350–500 mL	
		DDVP Smoke Fumigator	1/300 m^3	
		Nicotine Smoke Fumigator	1/300 m^3	
	Two-Spotted Spider Mite	Floramite SC	133 mL/400 L (333 mL/1000 L)	
		Avid 1.9% EC	300 mL	
		Dyno-Mite 75 W	142–284 g (5–10 PVA bags)	
		Kelthane 50 W	525–700 g	
		Malathion 25 W	2.5–5.0 kg	
		DDVP Smoke Fumigator	1/300 m^3	
		Insecticidal Soap	20 L	
	Whitefly	Intercept 60 WP	Read label carefully	
		Tristar 70 WSP	80-160 g (5-10 water soluble packs)	
		Enstar II	250–750 g	
		Dyno-Mite 75 W	284–425 g (10–15 PVA bags)	
		Endeavor 50 WG	200 g	Suppression only
		Trumpet 80 W	0.75–1.0 kg	
		Insecticidal Soap	20 L	
		Thiodan 50 WP	1.0–1.5 kg	
		Thiodan 4 EC	1.25–1.75 L	
		Endosulfan 50 W	1.0 kg	
		Thionex EC	1.25–1.75 L	
		DDVP Smoke Fumigator	1/300 m^3	
		DDVP 20% EC	6 L	
		Dursban WSP	448 g (4 water soluble packs)	
		Dursban 2E	1 L	
		Pyrate 480 EC	500 mL	
		Malathion 25 W	2.5–5.0 kg	
	Botrytis	Decree 50 WDG	1.12 kg	Apply using high-volume or low-volume equipment at 1.12 kg/ha
		Rovral 50% WP	1.0 kg	
		Senator	650–850 g	

TABLE 10–2. Pesticide Recommendations — By Crop (cont'd)

Plant Name	Problem	Recommendation by Trade Name	Rate/1,000 L (exceptions noted)	Remarks
Cyclamen	Aphid	Intercept 60 WP	Read label carefully	
		Tristar 70 WSP	48 g (3 water soluble packs)	
		Endeavor 50 WG	100–200 g	
		Enstar II	250–750 mL	
		Nicotine Smoke Fumigator	1/300 m^3	
		Trumpet 80 W	0.75–1.0 kg	
		Thiodan 50 WP	1.0–1.5 kg	
		Thiodan 4 EC	1.25–1.75 L	
		Endosulfan 50 W	1.0 kg	
		Thionex EC	1.25–1.75 L	
		Malathion 25 W	2.5–5.0 kg	
		DDVP Smoke Fumigator	1/300 m^3	
		DDVP 20% EC	6 L	
		Insecticidal Soap	20 L	
	Cyclamen Mite	Kelthane 50 W	525–700 g	
		Thiodan 50 WP	1.0–1.5 kg	
		Thiodan 4 EC	1.25–1.75 L	
		Endosulfan 50 W	1.0 kg	
		Thionex EC	1.25–1.75 L	
	Fungus Gnat	Citation 75 WP	133 g	Drench
		Dimilin 25 WP	18–150 g	Drench or soil surface spray
		Vectobac 600 L	2–8 L	Drench
		Trumpet 80 W	1.25 kg	Soil surface spray
	Shoreflies	Citation 75 WP	133 g	Drench
		Dimilin 25 WP	18–150 g	Drench or soil surface spray
	Thrips	Success 480 SC	50 mL	
	Two-Spotted Spider Mite	Floramite SC	133 mL/400 L 333 mL/1000 L	
		Avid 1.9% EC	300 mL	
		Dyno-Mite 75 W	142–284 g (5–10 PVA bags)	
		Insecticidal Soap	20 L	
		Kelthane 50 W	525–700 g	
		DDVP Smoke Fumigator	1/300 m^3	
		Malathion 25 W	2.5–5.0 kg	
	Botrytis	Decree 50 WDG	1.12 kg	Apply using high-volume or low-volume equipment at 1.12 kg/ha
		Phyton-27	1.25–2.5 L	
		Rovral 50% WP	1.0 kg	
		Senator	650–850 g	

TABLE 10–2. Pesticide Recommendations — By Crop (cont'd)

Plant Name	Problem	Recommendation by Trade Name	Rate/1,000 L (exceptions noted)	Remarks
Cyclamen (cont'd)	*Fusarium*	Senator 70 WP	650–850 g	Drench
		Mycostop	2–10 g /100m^2 (seedling production) 5–10 mg/plant (potted plants)	
		RootShield Drench	600–900 g	
		RootShield Granules	600 g/m^3	Soil mix
Exacum	Two-Spotted Spider Mite	Floramite SC	133 mL/400 L (333 mL/1000 L)	
		Avid 1.9% EC	300 mL	
		Dyno-Mite 75 W	142–284 g (5–10 PVA bags)	
		Kelthane 50 W	525–700 g	
		Insecticidal Soap	20 L	
		Malathion 25 W	2.5–5.0 kg	
		DDVP Smoke Fumigator	1/300 m^3	
	Botrytis	Decree 50 WDG	1.12 kg/ha	Test on a few plants before applying to new crops
		Rovral 50% WP	1.0 kg	
Foliage Plants	**Note: Due to the diversity of foliage plants and the lack of factual information on varietal damage, these recommendations are for trial use only.**			
	Aphid	Intercept 60 WP	Read label carefully	
		Tristar 70 WSP	48 g (3 water soluble packs)	
		Endeavor 50 WG	100–200 g	
		Enstar II	250–750 g	
		Pirliss 50 DF	500 g	
		Trumpet 80 W	0.75–1.0 kg	
		Insecticidal Soap	20 L	
		Malathion 25 W	2.5–5.0 kg	
		Thiodan 50 WP	1.0–1.5 kg	
		Thiodan 4 EC	1.25–1.75 L	
		Endosulfan 50 W	1.0 kg	
		Thionex EC	1.25–1.75 L	
		DDVP Smoke Fumigator	1/300 m^3	
		DDVP 20% EC	6 L	
		Nicotine Smoke Fumigator	1/300 m^3	
	Cyclamen Mite	Kelthane 50 W	525–700 g	
		Thiodan 50 WP	1.0–1.5 kg	
		Thiodan 4 EC	1.25–1.75 L	
		Endosulfan 50 W	1.0 kg	
		Thionex EC	1.25–1.75 L	
	Fungus Gnat	Citation 75 WP	133 g	Drench
		Dimilin 25 WP	18–150 g	Drench or soil surface spray

TABLE 10–2. Pesticide Recommendations — By Crop (cont'd)

Plant Name	Problem	Recommendation by Trade Name	Rate/1,000 L (exceptions noted)	Remarks
Foliage Plants (cont'd)	Fungus Gnat (cont'd)	Vectobac 600 L	2–8 L	Drench
		Trumpet 80 W	1.25 kg	Soil surface spray
	Mealybug	Malathion 25 W	2.5–5.0 kg	
		DDVP Smoke Fumigator	1/300 m^3	
		Trumpet 80 W	0.75–1.0 kg	
		Dursban WSP	224 g (2 water soluble packs)	
		Pyrate 480 EC	200 mL	
		Insecticidal Soap	20 L	
	Scale	Trumpet 80 W	750 g	
		Dursban WSP	1.792 kg (16 water soluble packs)	
		Dursban 2E	4 L	
		Pyrate 480 EC	2 L	
		Insecticidal Soap	20 L	
	Shoreflies	Citation 75 WP	133 g	Drench
		Dimilin 25 WP	18–150 g	Drench or soil surface spray
	Two-Spotted Spider Mite	Floramite SC	133 mL/400 L (333 mL/1000 L)	
		Avid 1.9% EC	300 mL	Do not use on ferns
		Dyno-Mite 75 W	142–284 g (5–10 PVA bags)	
		Insecticidal Soap	20 L	
		Kelthane 50 W	525–700 g	
		DDVP Smoke Fumigator	1/300 m^3	
		Malathion 25 W	2.5–5.0 kg	
	Whitefly	Intercept 60 WP	Read label carefully	
		Tristar 70 WSP	80-160 g (5-10 water soluble packs)	
		Dyno-Mite 75 W	284–425 g (10–15 PVA bags)	
		Enstar II	250–750 g	
		Endeavor 50 WG	200 g	Suppression only
		Trumpet 80 W	0.75–1.0 kg	
		Insecticidal Soap	20 L	
		Thiodan 50 WP	1.0–1.5 kg	
		Thiodan 4 EC	1.25–1.75 L	
		Endosulfan 50 W	1.0 kg	
		Thionex EC	1.25–1.75 L	
		Dursban WSP	448 g (4 water soluble packs)	
		Dursban 2E	1 L	
		Pyrate 480 EC	500 mL	
		DDVP Smoke Fumigator	1/300 m^3	
		DDVP 20% EC	6 L	
		Malathion 25 W	2.5–5.0 kg	
		Pounce 384 EC	260 mL	

TABLE 10–2. Pesticide Recommendations — By Crop (cont'd)

Plant Name	Problem	Recommendation by Trade Name	Rate/1,000 L (exceptions noted)	Remarks
Foliage Plants (cont'd)	*Botrytis*	Decree 50 WDG	1.12 kg	Apply using high-volume or low-volume equipment at 1.12 kg/ha
		Rovral 50% WP	1.0 kg	
		Senator 70 WP	650–850 g	
	Root Rot (Cuttings) *Phytophthora*	Truban 30% WP	500–750 g 55–110 g/m^3	Drench Dry soil mix
		Truban 25 EC	300–630 mL	
		Subdue Maxx	5 mL/m^3	Soil mix at seeding and transplanting
		Aliette	2.8 kg	Foliar application
		RootShield Drench	600–900 g	
		RootShield Granules	600 g/m^3	Soil mix
		Mycostop Biofungicide	Read label carefully	
	Rhizoctonia	Compass 50 WG	38 g	
		Supra Captan 80 WDG	1.5 kg	Soil treatment
		Maestro 75 DF	1.5 kg	Soil treatment
		Senator 70 WP	650–850 g	Drench
		RootShield Drench	600–900 g	
		RootShield Granules	600 g/m^3	Soil mix
	Leaf Spots and Blights	Daconil 2787	2.5 L	
		Senator 70 WP	650–850 g	
Geranium	Aphid	Intercept 60 WP	Read label carefully	
		Tristar 70 WSP	48 g (3 water soluble packs)	
		Endeavor 50 WG	100–200 g	
		Enstar II	250–750 mL	
		Insecticidal Soap	20 L	
		DDVP Smoke Fumigator	1/300 m^3	
		DDVP 20% EC	6 L	
		Trumpet 80 W	0.75–1.0 kg	
		Nicotine Smoke Fumigator	1/300 m^3	
		Malathion 25 W	2.5–5.0 kg	
	Fungus Gnat	Citation 75 WP	133 g	Drench
		Dimilin 25 WP	18–150 g	Drench or soil surface spray
		Vectobac 600 L	2–8 L	Drench
		Trumpet 80 W	1.25 kg	Soil surface spray
	Mealybug	Trumpet 80 W	0.75–1.0 kg	
		Malathion 25 W	2.5–5.0 kg	
		Insecticidal Soap	20 L	
		DDVP Smoke Fumigator	1/300 m^3	
	Shoreflies	Citation 75 WP	133 g	Drench
		Dimilin 25 WP	18–150 g	Drench or soil surface spray

TABLE 10–2. Pesticide Recommendations — By Crop (cont'd)

Plant Name	Problem	Recommendation by Trade Name	Rate/1,000 L (exceptions noted)	Remarks
Geranium (cont'd)	Two-Spotted Spider Mite	Floramite SC	133 mL/400 L (333 mL/1000 L)	
		Avid 1.9% EC	300 mL	
		Dyno-Mite 75 W	142–284 g (5–10 PVA bags)	
		Kelthane 50 W	525–700 g	
		Insecticidal Soap	20 L	
		Malathion 25 W	2.5–5.0 kg	
		DDVP Smoke Fumigator	1/300 m^3	
	Thrips	Success 480 SC	50 mL	
		Trumpet 80 W	0.75–1.0 kg 1.25 kg	Foliar spray Soil surface spray
		Malathion 25 W	2.5–5.0 kg	
		DDVP Smoke Fumigator	1/300 m^3	
		Nicotine Smoke Fumigator	1/300 m^3	
		Decis 5.0 EC	0.35–0.5 L	
	Whitefly	Intercept 60 WP	Read label carefully	
		Tristar 70 WSP	80-160 (5-10 water soluble packs)	
		Dyno-Mite 75 W	284–425 g (10–15 PVA bags)	
		Trumpet 80 W	0.75–1.0 kg	
		Enstar II	250– 750 mL	
		Endeavor 50 WG	200 g	Suppression only
		Insecticidal Soap	20 L	
		Pounce 384 EC	260 mL	
		DDVP Smoke Fumigator	1/300 m^3	
		DDVP 20% EC	6 L	
		Malathion 25 W	2.5–5.0 kg	
	Botrytis	Decree 50 WDG	1.12 kg	Apply using high-volume or low-volume equipment at 1.12 kg/ha
		Phyton-27	2.5 L	
		Botran 75% WP	925 g	
		Daconil 2787	2.5 L	Foliage only
		Rovral 50% WP	1.0 kg	
		Senator 70 WP	650–850 g	
	Damping-off *Rhizoctonia*	Supra Captan 80 WDG	1.5 kg	Soil treatment
		Maestro 75 DF	1.5 kg	Soil treatment
		Senator 70 WP	650–850 g	Drench
		RootShield Drench	600–900 g	
		RootShield Granules	600 g/m^3	Soil mix
		No-Damp	10 L	

TABLE 10–2. Pesticide Recommendations — By Crop (cont'd)

Plant Name	Problem	Recommendation by Trade Name	Rate/1,000 L (exceptions noted)	Remarks
Geranium (cont'd)	Stem and Root Rots *Pythium/Phytophthora*	Subdue Maxx	5 mL/m^3	Soil mix at seeding and transplanting
		Truban 25% EC	300–600 mL	Drench
		Aliette WDG	2.8 kg	Foliar spray
		RootShield Drench	600–900 g	
		RootShield Granules	600 g/m^3	Soil mix
		Mycostop Biofungicide	Read label carefully	
	Rust	Nova 40 W	340 g	
		Daconil 2787	2.5 L	Foliage only
Gerbera	Aphids	Intercept 60 WP	Read label carefully	
		Tristar 70 WSP	48 g (3 water soluble packs)	
		Endeavor 50 WG	100–200 g	
		Enstar II	250–750 g	
		Pirliss 50 DF	500 g	
		Trumpet 80 W	0.75–1.0 kg	
		Insecticidal Soap	20 L	
		Malathion 25 W	2.5–5.0 kg	
		Thiodan 50 WP	1.0–1.5 kg	
		Thiodan 4 EC	1.25–1.75 L	
		Endosulfan 50 W	1.0 kg	
		Thionex EC	1.25–1.75 L	
		DDVP Smoke Fumigator	1/300 m^3	
		DDVP 20% EC	6 L	
		Dibrom Insecticide	10 mL/100 m^3	
		Nicotine Smoke Fumigator	1/300 m^3	
	Fungus Gnat	Citation 75 WP	133 g	Drench
		Dimilin 25 WP	18–150 g	Drench or soil surface spray
		Vectobac 600 L	2–8 L	Drench
		Trumpet 80 W	1.25 kg	Soil surface spray
	Leafminer	Avid 1.9% EC	600 mL	
		Citation 75 WP	188 g	Can be used in LVMs at 188 g/ha
	Shoreflies	Citation 75 WP	133 g	Drench
		Dimilin 25 WP	18–150 g	Drench or soil surface spray
	Two-Spotted Spider Mite	Floramite SC	133 mL/400 L (333 mL/1000 L)	
		Avid 1.9% EC	300 mL	
		Dyno-Mite 75W	142–284 g (5–10 PVA bags)	
		Kelthane 50 W	525–700 g	
		Insecticidal Soap	20 L	
		Malathion 25 W	2.5–5.0 kg	
		DDVP Smoke Fumigator	1/300 m^3	
		Dibrom Insecticide	10 mL/100 m^3	

TABLE 10–2. Pesticide Recommendations — By Crop (cont'd)

Plant Name	Problem	Recommendation by Trade Name	Rate/1,000 L (exceptions noted)	Remarks
Gerbera (cont'd)	Thrips	Success 480 SC	50 mL	
		Trumpet 80 W	0.75–1.0 kg 1.25 kg	Foliar spray Soil surface spray
		Dursban WSP	448 g (4 water soluble packs)	
		Dursban 2E	1 L	
		Pyrate 480 EC	500 mL	
		DDVP Smoke Fumigator	1/300 m^3	
		Malathion 25 W	2.5–5.0 kg	
		Nicotine Smoke Fumigator	1/300 m^3	
	Whitefly	Intercept 60 WP	Read label carefully	Coconut growing medium may bind Intercept, making it unavailable to plants
		Tristar 70 WSP	80-160 g (5-10 water soluble packs)	
		Dyno-Mite 75 W	284–425 g (10–15 PVA bags)	
		Enstar II	250–750 mL	
		Insecticidal Soap	20 L	
		Endeavor 50 WG	200 g	Suppression only
		Dursban WSP	448 g (4 water soluble packs)	
		Dursban 2E	1 L	
		Pyrate 480 EC	500 mL	
		Trumpet 80 W	0.75–1.0 kg	
		Thiodan 50 WP	1.0–1.5 kg	
		Thiodan 4 EC	1.25–1.75 L	
		Endosulfan 50 W	1.0 kg	
		Thionex EC	1.25–1.75 L	
		Pounce 384 EC	260 mL	
		Malathion 25 W	2.5–5.0 kg	
		DDVP Smoke Fumigator	1/300 m^3	
		DDVP 20% EC	6 L	
		Dibrom Insecticide	10 mL/100 m^3	
	Botrytis	Decree 50 WDG	1.12 kg	Apply using high-volume or low-volume equipment at 1.12 kg/ha
		Rovral 50 WP	1.0 kg	Trial on a few plants before large-scale application
		Senator 70 WP	650–850 g	
		Phyton 27	1.25–2.0 L	
	Powdery mildew	Nova 40 W	340 g	
	Root rots *Pythium/Phytophthora*	Subdue Maxx	5 mL/m^2	Soil mix at seeding and transplanting
		RootShield Drench	600–900 g	
		RootShield Granules	600 g/m^3	Soil mix
		Mycostop Biofungicide	Read label carefully	

TABLE 10–2. Pesticide Recommendations — By Crop (cont'd)

Plant Name	Problem	Recommendation by Trade Name	Rate/1,000 L (exceptions noted)	Remarks
Gloxinia	Aphid	Intercept 60 WP	Read label carefully	
		Endeavor 50 WG	100–200 g	
		Enstar II	250–750 mL	
		Insecticidal Soap	20 L	
		DDVP 20% EC	6 L	
		Thiodan 50 WP	1.0–1.5 kg	
		Thiodan 4 EC	1.25–1.75 L	
		Endosulfan 50 W	1.0 kg	
		Thionex EC	1.25–1.75 L	
		DDVP Smoke Fumigator	1/300 m^3	
		DDVP 20% EC	6 L	
		Malathion 25 W	2.5–5.0 kg	
		Nicotine Smoke Fumigator	1/300 m^3	
	Fungus Gnat	Citation 75 WP	133 g	Drench
		Dimilin 25 WP	18–150 g	Drench or soil surface spray
		Vectobac 600 L	2–8 L	Drench
	Shoreflies	Citation 75 WP	133 g	Drench
		Dimilin 25 WP	18–150 g	Drench or soil surface spray
	Thrips	Success 480 SC	50 mL	
		Dursban WSP	448 g (4 water soluble packs)	
		Dursban 2E	1 L	
		Pyrate 480 EC	500 mL	
		DDVP Smoke Fumigator	1/300 m^3	
		Malathion 25 W	2.5–5.0 kg	
		Nicotine Smoke Fumigator	1/300 m^3	
	Two-Spotted Spider Mite	Floramite SC	133 mL/400 L (333 mL/1000 L)	
		Avid 1.9% EC	300 mL	
		Dyno-Mite 75W	142–284 g (5–10 PVA bags)	
		Insecticidal Soap	20 L	
		Kelthane 50 W	525–700 g	
		Malathion 25 W	2.5–5.0 kg	
		DDVP Smoke Fumigator	1/300 m^3	
	Botrytis	Decree 50 WDG	1.12 kg/ha	Apply using high-volume or low-volume equipment at 1.12 kg/ha
		Rovral 50 WP	1.0 kg	Trial on a few plants before large-scale application
		Daconil 2787	2.5 L	
		Senator 70 WP	650–850 g	

TABLE 10–2. Pesticide Recommendations — By Crop (cont'd)

Plant Name	Problem	Recommendation by Trade Name	Rate/1,000 L (exceptions noted)	Remarks
Gloxinia (cont'd)	Root and Stem Rot *Pythium/Phytophthora*	Subdue Maxx	5 mL/m^3	Soil mix at seeding and transplanting
		RootShield Drench	600–900 g	
		RootShield Granules	600 g/m^3	Soil mix
		Mycostop Biofungicide	Read label carefully	
Gypsophila	Leafminer	Avid 1.9% EC	600 mL	
		Citation 75 WP	188 g	Can be used in LVMs at 188 g/ha
	Two-Spotted Spider Mite	Floramite SC	133 mL/400 L (333 mL/1000 L)	
		Avid 1.9% EC	300 mL	
		Dyno-Mite 75 W	142–284 g (5–10 PVA bags)	
		Kelthane 50 W	525–700 g	
		Insecticidal Soap	20 L	
		Malathion 25 W	2.5–5.0 kg	
		DDVP Smoke Fumigator	1/300 m^3	
		Dibrom Insecticide	10 mL/100 m^3	
	Thrips	Success 480 SC	50 mL	
		Trumpet 80 W	0.75–1.0 kg 1.25 kg	Foliar spray Soil surface spray
		Dursban WSP	448 g (4 water soluble packs)	
		Dursban 2E	1 L	
		Pyrate 480 EC	500 mL	
		DDVP Smoke Fumigator	1/300 m^3	
		Malathion 25 W	2.5–5.0 kg	
		Nicotine Smoke Fumigator	1/300 m^3	
Hydrangea	Aphid	Intercept 60 WP	Read label carefully	
		Tristar 70 WSP	48 g (3 water soluble packs)	
		Endeavor 50 WG	100–200 g	
		Enstar II	250–750 mL	
		Insecticidal Soap	20 L	
		Trumpet 80 W	0.75–1.0 kg	
		Thiodan 50 WP	1.0–1.5 kg	
		Thiodan 4 EC	1.25–1.75 L	
		Endosulfan 50 W	1.0 kg	
		Thionex EC	1.25–1.75 L	
		DDVP Smoke Fumigator	1/300 m^3	
		DDVP 20% EC	6 L	
		Malathion 25 W	2.5–5.0 kg	
		Nicotine Smoke Fumigator	1/300 m^3	
	Fungus Gnat	Citation 75 WP	133 g	Drench

TABLE 10–2. Pesticide Recommendations — By Crop (cont'd)

Plant Name	Problem	Recommendation by Trade Name	Rate/1,000 L (exceptions noted)	Remarks
Hydrangea (cont'd)	Fungus Gnat (cont'd)	Dimilin 25 WP	18–150 g	Drench or soil surface spray
		Vectobac 600 L	2–8 L	Drench
		Trumpet 80 W	1.25 kg	Soil surface spray
	Shoreflies	Citation 75 WP	133 g	Drench
		Dimilin 25 WP	18–150 g	Drench or soil surface spray
	Two-Spotted Spider Mite	Floramite SC	133 mL/400 L (333 mL/1000 L)	
		Avid 1.9% EC	300 mL	
		Dyno-Mite 75W	142–284 g (5–10 PVA bags)	
		Kelthane 50 W	525–700 g	
		Insecticidal Soap	20 L	
		Malathion 25 W	2.5–5.0 kg	
		DDVP Smoke Fumigator	1/300 m^3	
	Botrytis	Decree 50 WDG	1.12 kg	Apply using high-volume or low-volume equipment at 1.12 kg/ha
		Rovral 50% WP	1.0 kg	
		Senator 70 WP	650–850 g	
	Leaf Spots	Daconil 2787	2.5 L	On foliage only
		Senator 70 WP	650–850 g	
	Powdery mildew	Milstop	5.6 kg/ha (2000 L water/ha)	
	Rust	Daconil 2787	2.5 L	On foliage only
Lily (Easter)	Aphid	Intercept 60 WP	Read label carefully	
		Tristar 70 WSP	48 g (3 water soluble packs)	
		Endeavor 50 WG	100–200 g	
		Enstar II	250–750 mL	
		Trumpet 80 W	0.75–1.0 kg	
		Insecticidal Soap	20 L	
		DDVP Smoke Fumigator	1/300 m^3	
		DDVP 20% EC	6 L	
		Thiodan 50 WP	1.0–1.5 kg	
		Thiodan 4 EC	1.25–1.75 L	
		Endosulfan 50 W	1.0 kg	
		Thionex EC	1.25–1.75 L	
		Malathion 25 W	2.5–5.0 kg	
		Nicotine Smoke Fumigator	1/300 m^3	
	Fungus Gnat	Citation 75 WP	133 g	Drench
		Dimilin 25 WP	18–150 g	Drench or soil surface spray
		Vectobac 600 L	2–8 L	Drench
		Trumpet 80 W	1.25 kg	Soil surface spray

TABLE 10–2. Pesticide Recommendations — By Crop (cont'd)

Plant Name	Problem	Recommendation by Trade Name	Rate/1,000 L (exceptions noted)	Remarks
Lily (Easter) (cont'd)	Shoreflies	Citation 75 WP	133 g	Drench
		Dimilin 25 WP	18–150 g	Drench or soil surface spray
	Two-Spotted Spider Mite	Floramite SC	133 mL/400 L (333 mL/1000 L)	
		Dyno-Mite 75W	142–284 g (5–10 PVA bags)	
		Avid 1.9% EC	300 mL	
		Insecticidal Soap	20 L	
		Kelthane 50 W	525–700 g	
		DDVP Smoke Fumigator	1/300 m^3	
		Malathion 25 W	2.5–5.0 kg	
	Thrips	Success 480 SC	50 mL	
		Trumpet 80 W	0.75–1.0 kg 1.25 kg	Foliar spray Soil surface spray
		Dursban WSP	448 g (4 water soluble packs)	
		Dursban 2E	1 L	
		Pyrate 480 EC	500 mL	
		DDVP Smoke Fumigator	1/300 m^3	
		Malathion 25 W	2.5–5.0 kg	
		Decis 5.0 EC	0.35–0.5 L	
		Nicotine Smoke Fumigator	1/300 m^3	
	Botrytis	Decree 50 WDG	1.12 kg	Apply using high-volume or low-volume equipment at 1.12 kg/ha
		Rovral 50% WP	1.0 kg	
		Daconil 2787	2.5 L	
		Senator 70 WP	650–850 g	
	Root Rot *Pythium*	Truban 30% WP	500–750 g 55–110 g/m^3	Drench Dry soil mix
		Subdue Maxx	5 mL/m^3	Soil mix at seeding and transplanting
		RootShield Drench	600–900 g	
		RootShield Granules	600 g/m^3	Soil mix
		Mycostop Biofungicide	Read label carefully	
Poinsettia	Brown Soft Scale	Trumpet 80 W	750 g	
		Insecticidal Soap	20 L	
	Fungus Gnat	Citation 75 WP	133 g	Drench
		Vectobac 600 L	2–8 L	Drench
		Trumpet 80 W	1.25 kg	Soil surface spray
	Mealybug	Malathion 25 W	2.5–5.0 kg	
		DDVP Smoke Fumigator	1/300 m^3	
		Insecticidal Soap	20 L	
		Trumpet 80 W	0.75–1.0 kg	

TABLE 10–2. Pesticide Recommendations — By Crop (cont'd)

Plant Name	Problem	Recommendation by Trade Name	Rate/1,000 L (exceptions noted)	Remarks
Poinsetta (cont'd)	Shoreflies	Citation 75 WP	133 g	Drench
	Two-Spotted Spider Mite	Floramite SC	133 mL/400 mL (333 mL/1000 L)	Also registered to control Lewis mite
		Avid 1.9% EC	300 mL	
		Dyno-Mite 75 W	142–284 g (5–10 PVA bags)	Avoid pesticide application after bract colour, as damage may occur
		Kelthane 50 W	525–700 g	
		Insecticidal Soap	20 L	
		DDVP Smoke Fumigator	1/300 m^3	
		Malathion 25 W	2.5–5.0 kg	
	Whitefly	Intercept 60 WP	Read label carefully	
		Tristar 70 WSP	80-160 g (5-10 water soluble packs)	
		Dyno-Mite 75 W	284–425 g (10–15 PVA bags)	Avoid pesticide application after bract colour, as damage may occur
		Enstar II	250–750 mL	
		Trumpet 80 W	0.75–1.0 kg	
		Endeavor	200 g	Suppression only
		DDVP Smoke Fumigator	1/300 m^3	
		DDVP 20% EC	6 L	
		Thiodan 50 WP	1.0–1.5 kg	
		Thiodan 4 EC	1.25–1.75 L	
		Endosulfan 50 W	1.0 kg	
		Thionex EC	1.25–1.75 L	
		Insecticidal Soap	20 L	
		Malathion 25 W	2.5–5.0 kg	
		Pounce 384	260 mL	
	Botrytis	Decree 50 WDG	1.12 kg	Apply using high-volume or low-volume equipment at 1.12 kg/ha
		Rovral 50% WP	1.0 kg	
		Senator 70 WP	650–850 g	
		Phyton-27	1.5 L	
	Damping-off Stem Rots *Pythium*	Subdue Maxx	5 mL/m^3	Soil mix at seeding and transplanting
		Truban 30 WP	500–750 g 55–110 g/m^3	Drench Dry soil mix
		RootShield Drench	600–900 g	
		RootShield Granules	600 g/m^3	Soil mix
		Mycostop Biofungicide	Read label carefully	
	Rhizoctonia	Compass 50 WG	38 g	
		Supra Captan 80 WDG	1.5 kg	Soil treatment
		Maestro 75 DF	1.5 kg	Soil treatment

TABLE 10–2. Pesticide Recommendations — By Crop (cont'd)

Plant Name	Problem	Recommendation by Trade Name	Rate/1,000 L (exceptions noted)	Remarks
Poinsetta (cont'd)	Damping-off Stem Rots (cont'd)	Senator 70 WP	650–850 g	Drench
		Quintozene 75% WP	1.25 kg	Drench
		RootShield Drench	600–900 g	
		RootShield Granules	600 g/m^3	Soil mix
		Mycostop Biofungicide	Read label carefully	
	Powdery Mildew	Nova 40 W	280 g	
		Milstop	5.6 kg/ha (2000 L water/ha)	
		Phyton-27	1.25 L	
	Stem and Root Rot *Pythium/ Phytophthora*	Subdue Maxx	5 mL/m^3	Soil mix at seeding and transplanting
		Truban 30 WP	500–750 g 55–110 g/m^3	Drench Dry soil mix
		RootShield Drench	600–900 g	
		RootShield Granules	600 g/m^3	Soil mix
		Mycostop Biofungicide	Read label carefully	
		Folpan 50 WP	2.0–2.25 kg	
	Rhizoctonia	Compass 50 WG	38 g	
		Quintozene 75% WP	1.25 kg	Drench
		Supra Captan 80 WDG	1.5 kg	Soil treatment
		Maestro 75 DF	1.5 kg	Soil treatment
		Senator 70 WP	650–850 g	
		RootShield Drench	600–900 g	
		RootShield Granules	600 g/m^3	Soil mix
	Erwinia	Phyton-27	1.25–2.5 L	Cutting dip
Rose	Aphid	Intercept 60 WP	Read label carefully	
		Tristar 70 WSP	48 g (3 water soluble packs)	
		Endeavor 50 WG	100–200 g	
		Trumpet 80 W	0.75–1.0 kg	
		Pirliss 50 DF	500 g	
		DDVP Smoke Fumigator	1/300 m^3	
		DDVP 20% EC	6 L	
		Thiodan 50 WP	1.0–1.5 kg	
		Thiodan 4 EC	1.25–1.75 L	
		Endosulfan 50 W	1.0 kg	
		Thionex EC	1.25–1.75 L	
		Enstar II	250–750 mL	
		Nicotine Smoke Fumigator	1/300 m^3	
		Orthene 75% SP	850 g	
		Insecticidal Soap	20 L	
		Malathion 50 EC	2.0 L	
		Malathion 25 W	2.5–5.0 kg	
		Dibrom Insecticide	10 mL/100 m^3	
	Scale	Trumpet 80 W	750 g	
		Insecticidal Soap	20 L	

TABLE 10–2. Pesticide Recommendations — By Crop (cont'd)

Plant Name	Problem	Recommendation by Trade Name	Rate/1,000 L (exceptions noted)	Remarks
Rose (cont'd)	Fungus Gnat	Citation 75 WP	133 g	Drench
		Dimilin 25 WP	18–150 g	Drench or soil surface spray
		Vectobac 600 L	2–8 L	Drench
		Trumpet 80 W	1.25 kg	Soil surface spray
	Leafroller	Dipel DF	625 g	
		Dipel WP	1.25 kg	
		Thuricide HPC	5 L	
		BioProtec CAF	1.8 L	
		Confirm 240 F	1 L	
		Orthene 75% SP	850 g	
		Dibrom Insecticide	10 mL/100m^3	
	Midge	Orthene 75% SP	850 g	
		Nicotine Smoke Fumigator	1/300 m^3	
	Shoreflies	Citation 75 WP	133 g	Drench
		Dimilin 25 WP	18–150 g	Drench or soil surface spray
	Thrips	Success 480 SC	50 mL	
		Trumpet 80 W	0.75–1.0 kg 1.25 kg	Foliar spray Soil surface spray
		Orthene 75 SP	850 g	
		Malathion 50 EC	2.0 L	
		Malathion 25 W	2.5–5.0 kg	
		DDVP Smoke Fumigator	1/300 m^3	
		Nicotine Smoke Fumigator	1/300 m^3	
	Two-Spotted Spider Mite	Floramite SC	133 mL/400 L (333 mL/1000 L)	
		Avid 1.9% EC	300 mL	
		Dyno-Mite 75W	142–284 g (5–10 PVA bags)	
		Kelthane 50 W	525–700 g	
		Insecticidal Soap	20 L	
		DDVP Smoke Fumigator	1/300 m^3	
		Malathion 50 EC	2.0 L	
		Malathion 25 W	2.5–5.0 kg	
		Dibrom Insecticide	10 mL/100 m^3	
	Whitefly	Intercept 60 WP	Read label carefully	Coconut growing medium may bind Intercept, making it unavailable to plants
		Tristar 70 WSP	80-160 g (5-10 water soluble packs)	
		Dyno-Mite 75 W	284–425 g (10–15 PVA bags)	
		Insecticidal Soap	20 L	
		Trumpet 80 W	0.75–1.0 kg	

TABLE 10–2. Pesticide Recommendations — By Crop (cont'd)

Plant Name	Problem	Recommendation by Trade Name	Rate/1,000 L (exceptions noted)	Remarks
Rose (cont'd)	Whitefly (cont'd)	Enstar II	250–750 mL	
		Endeavor 50 WG	200 g	Suppression only
		Thiodan 50 WP	1.0–1.5 kg	
		Thiodan 4 EC	1.25–1.75 L	
		Endosulfan 50 W	1.0 kg	
		Thionex EC	1.25–1.75 L	
		Orthene 75% SP	850 g	
		DDVP Smoke Fumigator	1/300 m^3	
		DDVP 20% EC	6 L	
		Malathion 50 EC	2.0 L	
		Malathion 25 W	2.5–5.0 kg	
		Pounce 384 EC	260 mL	
		Dibrom Insecticide	10 mL/100 m^3	
	Black Spot	Daconil 2787	2.5 L	
		Supra Captan 80 WDG	1.25–1.5 kg	
		Maestro 75 DF	1.3–1.6 kg	
		Senator 70 WP	650–850 g	
	Powdery Mildew	Nova 40 W	340 g	
		Meltatox 40% EC	2.5 L	
		Phyton-27	1.25–2.5 L	
	Botrytis	Decree 50 WDG	1.12 kg	Apply using high-volume or low-volume equipment at 1.12 kg/ha
		Rovral 50 WP	1.0 kg	
		Daconil 2787	2.5 L	
		Senator 70 WP	650–850 g	
		Phyton-27	1.25–2.5 L 0.8–1.0 mL/L	Foliar spray Dip flowerbud for 4 seconds shortly after harvesting
		Botran 75 W	925 g	
Snapdragon	Aphid	Intercept 60 WP	Read label carefully	
		Tristar 70 WSP	48 g (3 water soluble packs)	
		Endeavor 50 WG	100–200 g	
		Pirliss 50 DF	500 g	
		Enstar II	250–750 mL	
		Trumpet 80 W	0.75–1.0 kg	
		Insecticidal Soap	20 L	
		Thiodan 50 WP	1.0–1.5 kg	
		Thiodan 4 EC	1.25–1.75 L	
		Endosulfan 50 W	1.0 kg	
		Thionex EC	1.25–1.75 L	
		Malathion 25 W	2.5–5.0 kg	
		Nicotine Smoke Fumigator	1/300 m^3	
		DDVP Smoke Fumigator	1/300 m^3	

TABLE 10–2. Pesticide Recommendations — By Crop (cont'd)

Plant Name	Problem	Recommendation by Trade Name	Rate/1,000 L (exceptions noted)	Remarks
Snapdragon (cont'd)	Aphid (cont'd)	DDVP 20% EC	6 L	
		Dibrom Insecticide	10 mL/100 m^3	
	Cyclamen Mite	Kelthane 50 W	525–700 g	
		Thiodan 50 WP	1.0–1.5 kg	
		Thiodan 4 EC	1.25–1.75 L	
		Endosulfan 50 W	1.0 kg	
		Thionex EC	1.25–1.75 L	
	Fungus Gnat	Citation 75 WP	133 g	Drench
		Dimilin 25 WP	18–150 g	Drench or soil surface spray
		Vectobac 600 L	2–8 L	Drench
		Trumpet 80 W	1.25 kg	Soil surface spray
	Shoreflies	Citation 75 WP	133 g	Drench
		Dimilin 25 WP	18–150 g	Drench or soil surface spray
	Thrips	Success 480 SC	50 mL	
		Trumpet 80 W	0.75–1.0 kg 1.25 kg	Foliar spray Soil surface spray
		DDVP Smoke Fumigator	1/300 m^3	
		Dursban WSP	448 g (4 water soluble packs)	
		Dursban 2E	1 L	
		Pyrate 480 EC	500 mL	
		Nicotine Smoke Fumigator	1/300 m^3	
		Malathion 25 W	2.5–5.0 kg	
	Two-Spotted Spider Mite	Floramite SC	133 mL/400 L (333 mL/1000 L)	
		Avid 1.9% EC	300 mL	
		Dyno-Mite 75 W	142–284 g (5–10 PVA bags)	
		Insecticidal Soap	20 L	
		Kelthane 50 W	525–700 g	
		Malathion 25 W	2.5–5.0 kg	
		DDVP Smoke Fumigator	1/300 m^3	
		Dibrom Insecticide	10 mL/100 m^3	
	Whitefly	Intercept 60 WP	Read label carefully	
		Tristar 70 WSP	80-160 g (5-10 water soluble packs)	
		Dyno-Mite 75 W	284–425 g (10–15 PVA bags)	
		Enstar II	250–750 mL	
		Insecticidal Soap	20 L	
		Endeavor 50 WG	200 g	Suppression only
		Thiodan 50 WP	1.0–1.5 kg	
		Thiodan 4 EC	1.25–1.75 L	

TABLE 10–2. Pesticide Recommendations — By Crop (cont'd)

Plant Name	Problem	Recommendation by Trade Name	Rate/1,000 L (exceptions noted)	Remarks
Snapdragon (cont'd)	Whitefly (cont'd)	Endosulfan 50 W	1.0 kg	
		Thionex EC	1.25–1.75 L	
		DDVP Smoke Fumigator	1/300 m^3	
		DDVP 20% EC	6 L	
		Trumpet 80 W	0.75–1.0 kg	
		Dursban WSP	448 g (4 water soluble packs)	
		Dursban 2E	1 L	
		Pyrate 480 EC	500 mL	
		Malathion 25 W	2.5–5.0 kg	
		Dibrom Insecticide	10 mL/100 m^2	
	Botrytis	Decree 50 WDG	1.12 kg	Apply using high-volume or low-volume equipment at 1.12 kg/ha
		Rovral 50% WP	1.0 kg	
		Senator 70 WP	650–850 g	
	Stem Rot *Pythium*	Truban 30% WP	500–750 g 55–110 g/m^3	Drench Dry soil mix
		Subdue Maxx	5 mL/m^3	Soil mix at seeding and transplanting
		RootShield Drench	600–900 g	
		RootShield Granules	600 g/m^3	Soil mix
		Mycostop Biofungicide	Read label carefully	
	Rhizoctonia	Quintozene 75% WP	1.25 kg	Drench
		Senator 70 WP	650–850 g	Drench

11. Pest Control Products for Outdoor Herbaceous Ornamentals

Integrated Pest Management (IPM) in Outdoor Ornamentals (including field-grown cut flowers, perennials and potted plants)

IPM in outdoor ornamental and flower crops involves the same principles used in greenhouse production. However, there are some differences.

Monitoring is still the cornerstone of an IPM program, but there may be less reliance on the use of yellow sticky cards as an insect-monitoring tool due to wind-blown dust and debris collecting on them and limiting their usefulness. Regularly inspect crops to detect problems early. As with greenhouse-grown crops, there are large variations in the susceptibility of crops and varieties to diseases and insects. Knowing this can greatly increase the efficiency of crop inspections, by targeting first those crops that are most likely to have pests or diseases.

In outdoor production, there is no control over the weather. Cool, damp conditions will increase the likelihood of disease outbreaks. Strong winds may result in sudden and unexpected outbreaks of insect pests that have been blown in from elsewhere. Nevertheless, the environment outside will never be as perfect for pest development as it is in a greenhouse. Variability in weather such as cool or cold nights and rain can slow the development of pests compared to a similar situation in the greenhouse.

Biological control may not offer the same options for control as it does in the enclosed environment of greenhouses. For example, flying insects such as parasitic wasps are not constrained to stay in the crop. Predatory mites (which don't fly) may be useful but there has been little experience with them in these situations.

The use of pesticides outdoors also requires different thinking. Products registered for greenhouse use are not necessarily registered for outdoor ornamentals. See Table 11–1. *Insecticides/Miticides Registered for Use on Outdoor Ornamental Crops in Canada*, Table 11–2. *Fungicides Registered for Use on Outdoor Ornamental Crops in Canada* and Table 11–3. *Other Pesticides Registered for Use on Outdoor Ornamental Crops in Canada*, for more information. Be aware of the potential for drift into non-target areas, proximity to watercourses and ponds, and the impact on non-target organisms such as honeybees. Also, herbicides have a much more important role in outdoor flower production. See *Integrated Weed Management in Outdoor Flower Production*, on page 141.

TABLE 11–1. Insecticides/Miticides Registered for Use on Outdoor Ornamental Crops in Canada

Insecticides	Pests	Crops
Apollo (clofentezine)	Two-spotted spider mite	Outdoor deciduous nursery stock
Cygon 480, Lagon 480 (dimethoate)	Various insect pests (see label)	Outdoor ornamentals (see label)
Diazinon 500 E, Diazol 50 W, Diazol 50 EC, Diazinon 50 W, Diazinon 500 EC (diazinon)	Various insect pests (see label)	Various ornamentals (see label)
Dibrom (naled)	Aphids, leafhoppers, spider mites, other listed pests (see label)	Outdoor ornamentals (see label)
Dipel (*Bacillus thuringiensis kurstaki*)	Caterpillars	Woody ornamentals
Dursban WSP, Dursban 2E, Pyrate 480 EC (chlorpyrifos)	Various insect pests (see label)	Outdoor ornamental plants
Dyno-Mite (pyridaben)	Various mite pests (see label)	Outdoor ornamental plants
Imidan 50 WP (phosmet)	Elm spanworm, gypsy moth, Japanese beetle	Outdoor herbaceous plants (see label)
Insecticidal soap	Various insect and mite pests (see label)	Outdoor flowers, ornamentals (see label)
Kelthane 50 W (dicofol)	Mites	Outdoor ornamentals
Malathion 50 EC, Malathion 25W, Malathion 50 E (malathion)	Various insect and mite pests (see label)	Outdoor flowers and ornamentals
Orthene (acephate)	Aphids, caterpillars, lacebugs, leafhoppers, psyllids, rose midge, thrips, whitefly, mealybugs, scale, spider mites	Outdoor flowers, ornamentals, shrubs, trees, rose
Pirliss 50 DF (pirimicarb)	Aphids	Outdoor ornamentals (see label)
Sevin (carbaryl)	Various insect pests (see label)	Various outdoor ornamentals (see label)
Success 480 SC (spinosad)	Thrips and other pests (see label)	Outdoor ornamentals
Thiodan 50 WP, Thiodan 4 EC, Endosulfan 50 W, Endosulfan 400 E, Thionex EC (endosulfan)	Various insect and mite pests (see label)	Outdoor ornamentals
Tristar 70 WSP (acetamiprid)	Various insect pests (see label)	Ornamental and flowering plants

TABLE 11–2. Fungicides Registered for Use on Outdoor Ornamental Crops in Canada

Fungicides	Diseases	Crops
Botran 75 W (dicloran)	*Botrytis*	Rose, hydrangea (outdoors)
Compass 50 WG (trifloxystrobin)	Powdery mildew, scab, Rhizoctonia	Various outdoor ornamentals (see label)
Daconil 2787 (chlorothalonil)	Various diseases (see label)	Various outdoor ornamental crops (see label)
Decree 50 WDG (fenhexamid)	*Botrytis*	Outdoor ornamentals
Dithane DG (mancozeb)	Various foliar diseases (see label)	Woody ornamentals (see label)
Nova 40 W (myclobutanil)	Rusts, powdery mildew, leaf spots (see label)	Various outdoor ornamentals (see label)
Folpan 50 WP (folpet)	Various foliar diseases, root and stem rot (see label)	Various outdoor ornamentals (see label)
Funginex 190 EC (triforine)	Black spot of roses, powdery mildew	Outdoor ornamentals
Heritage (azoxystrobin)	Daylily rust	Daylilies
Maestro 75 DF, Captan 80W, Captan 50 W (captan)	Foliar diseases, damping-off, bulb rot (see label)	Outdoor ornamentals listed (see label)
Rovral (iprodione)	*Botrytis, Rhizoctonia*	Outdoor ornamentals (see label)
Senator 70 WP (thiophanate-methyl)	Black spot of roses, powdery mildew	Outdoor ornamentals
Subdue Maxx (metalaxyl)	*Pythium, Phytophthora*	Outdoor ornamentals
Zineb 80 W (zineb)	*Septoria* leaf spot of chrysanthemum, snapdragon rust	Chrysanthemum, snapdragon

TABLE 11–3. Other Pesticides Registered for Use on Outdoor Ornamental Crops in Canada

Pesticide	Pest	Crops
Deadline M-Ps (metaldehyde)	Slugs	Ornamentals
SlugEm (metaldehyde)	Slugs	Nurseries
Sluggo (ferric phosphate)	Slugs	Outdoor ornamentals, nurseries

The other major difference between greenhouse and outdoor production of flowers and other ornamental crops is in the need for weed management.

Integrated Weed Management in Outdoor Flower Production

A successful weed management program must integrate cultural and chemical weed control practices. Growers cannot depend entirely on chemical weed control in outdoor flower crops, since there is a limited spectrum of herbicides registered for these crops. There are many ways of reducing weed problems:

- Choose a low weed-pressure site:
    - **Select fields with lower weed pressure.** Problem weeds, e.g., annuals such as pigweed, ragweed and lamb's quarters, as well as perennials make weed control programs more difficult. Use a five-year plan to reduce weeds in your next plantings.
    - **Grow rotational crops that reduce weeds**, e.g., winter wheat in the previous year breaks the life cycle of annual weeds and allows the use of hormone herbicides (e.g. 2,4-D) to control broadleaf weeds.
    - **Grow crops with a wider choice in herbicides**, e.g., corn to reduce weed populations before planting flowers. Avoid persistent herbicides that may harm flower crops in future plantings.
- Prepare the site:
    - **Identify weeds.** Watch for these weeds common in outdoor flower production: perennial weeds like quackgrass, bindweed, vetch, wild grape, perennial nightshade, thistles, ground-ivy (creeping charlie), willowherb and burdock; and biennials like dandelions, wild carrot and biennial wormwood. Winter annuals like sow thistles, fleabanes, mustards, peppergrass, shepherd's purse and flixweed can also be a challenge because they establish through the fall.
    - **Eradicate perennial and biennial weeds.** It is important to identify and control these tough weeds in the preplanting year, because they are very difficult to control after planting. Apply systemic herbicides such as glyphosate (e.g., Roundup) to perennial weeds in the preplanting year. Use the recommended rate for each weed (note the higher rates recommended on labels for perennial weeds), and apply it when the weed reaches the sensitive stage of growth. Repeated cultivations of some perennial weeds such as bindweed will also provide control, but avoid dragging weeds to clean areas of the field. Use a sprayer designated solely for applying glyphosate to reduce the risk of damaging crops.
    - **Grow a green manure crop.** Cover crops like cereals, perennial ryegrass, pearl millet or Sudan-sorghum grown in the preplanting year will compete with weeds as well as improve soil structure. There are several key times to use herbicides in these crops to reduce weeds: before planting (non-selective herbicides e.g., glyphosate or Gramoxone), shortly after establishment of the green manure crop (short residual herbicides, e.g., 2,4-D, bromoxynil, dicamba), and before plowdown. Avoid using herbicides that leave a soil residue to carry over into the planting year (eg. Atrazine, simazine, Karmex).
- Avoid weeds in production years:
    - **Set up a stale seedbed.** This technique is useful for crops seeded or planted later in the spring. Cultivate the area as early as possible (April or early May) to encourage germination of weeds. Just before planting time, kill emerged weeds with herbicides (e.g., glyphosate, Gramoxone), flamers or steam. Plant directly into undisturbed soil to avoid bringing new weed seeds to the surface. For seeded crops, the burndown can be repeated if necessary (very carefully) just before the crop emerges. A plate of glass set on freshly worked ground will encourage weed seed germination and will signal when to apply this second burndown safely before the crop emerges.
    - **Manage weeds in row middles.** Cultivation can control weeds between the rows but will decrease soil organic matter. Alternatively, planting grass

strips between the rows will prevent weeds from becoming established. Choose a grass mixture of low-maintenance grasses that tolerate drought, like creeping red fescue or perennial ryegrass. Timely mowing can prevent weeds from seeding into crops. Use of sod row middles increases the need for irrigation and/or nitrogen fertilizer.

  - **Prevent weed seeds.** Control weeds in field edges and adjacent areas before they set seed. Try to control weed escapes in crops before they set seed, by cultural removal or chemical mowing. Mowing at regular intervals will prevent many weeds from flowering. Watch for weeds that sprout low branches that may flower lower than mower blades.

- Use many weed-control tools:

  - **Cultivation.** Generally, cultivating when weeds are small and soils are drying is most effective. Different cultivation tools work at different timings for different weeds. Rotary hoes, tine cultivators, rolling baskets, rotating disks, brushes and interplant cultivators may be effective in flower crops. Frequent hand hoeing when weeds are tiny can be quick and effective.

  - **Hilling.** Row crops like gladioli benefit from regular hilling to provide support for the plant as well as weed control. Equipment is available that can move soil toward the plants on one pass and pull it away on the next if a mound is not desirable.

  - **Mowing.** Small mowers can manoeuvre around many plants to mow weeds down. This can be very effective to prevent weed flowers and seeds but mowing does not eliminate weed competition for moisture. Weed whips are very useful for selective cutting, both with a blade and a string attachment. Removal of flower heads from the area may be needed to avoid seed shed after mowing.

  - **Flamers.** Equipment that directs a hot propane flame to kill weeds can be very effective. Driving speeds at 5–10 km/hr are required to avoid damage to the crop, so fields need to be designed with straight rows and large turning areas. Hand-held flamers are also available but quick movement of the flame is still important.

  - **Mulching.** A thick layer of mulch can prevent weed germination and conserve soil moisture. Apply weed-free mulch after planting but before weeds emerge. Use plastic mulch under short-term crops, and planters to plant through the plastic. Dark plastic gives the best weed control, although other colours may have other uses. Biodegradable plastics avoid the problem of disposal after use. Organic mulch materials, e.g. straw or fine wood chips, can work well but be sure to provide enough nitrogen for the plants as it decomposes. In the late fall, pull the mulch away from the base of the plant to discourage rodents over winter. Nursery ground-cover fabric can be especially useful for weed control in outdoor potted plant production and for perennial flowers that grow in clumps. This fabric is long-lasting, provides drainage and is not as slippery as plastic. It provides a weed-free area, is durable and easy to keep clean. Weeds will establish on the edges of all mulches, so regular edge weeding is necessary.

  - **Herbicides.** Table 11–4. *Herbicides Registered for Use on Outdoor Ornamental Crops in Canada*, shows a selection of herbicides registered for use on outdoor ornamental crops in Canada. Select a herbicide registered as safe on a crop and apply it as directed on the label. Keep a separate, clearly-marked sprayer for herbicides and wash it out properly between uses with a tank cleaner like Agral 90. Sprayers with shrouds can prevent herbicides from contacting the crop and other drift-reducing technologies like air-induction nozzles may be useful. Wick wiper applicators (either hand-held, tractor or ATV-mounted) can control weeds by wiping concentrated herbicides like glyphosate directly on weeds. Selective drip applicators are also available for very finely targeted applications next to flowers. Spot treatments can be very effective at controlling small patches of new weeds. For best results with glyphosate, wait until the flowering stage of perennial weeds like thistle or milkweed. Check equipment for drips and leaks before treating weeds to avoid dripping herbicide on the crop.

Note: Rotation of herbicide families (see Herbicide Groups in Table 11–4) is important to minimize the building up of seed from weed escapes, including triazine-tolerant weeds. Don't use herbicides from the same group year after year but switch between different group numbers. Rotation will also help avoid an accumulation of herbicide residues in the soil that may result in crop injury over a period of years and may hinder replanting.

TABLE 11–4. Herbicides Registered for Use on Outdoor Ornamental Crops in Canada

Herbicides	Weeds	Crops	Herbicide Group	Comments
Basamid Granular (fumigant) (dazomet)	PRE Germinating weed seeds	Outdoor flowers, ornamentals	27	• apply to weed-free soil • do not use below 6°C • open soil 5–7 days after treatment
Bonanza 400 (trifluralin) Treflan EC Rival 500 EC	PPI Annual grasses and broadleaf weeds (see label)	Perennials and woody ornamentals (see label)	3	• incorporate shallowly in two directions within 24 hours of application • place transplants' roots below treated layer
Dacthal W75 (chlorthal dimethyl)	PRE Various including lamb's quarters, crabgrass, lovegrass, carpetweed, witchgrass, purslane, foxtail, common chickweed (see label)	Outdoor ornamentals (see label)	3	• apply to weed-free soil • irrigate or shallowly incorporate within 3–5 days if no rain falls
Devrinol 50 DF Devrinol 2 G Devrinol 10 G (napropamide)	PRE Weed control (see label)	Outdoor flowers, ornamentals (see label)	15	• apply to weed-free soil • requires 1 cm of rainfall or irrigation within 7 days (spring or fall) or 2 days (summer) to prevent breakdown by sunlight • very safe on plants
Kerb 50 WSP (propyzamide)	PRE Quackgrass, annual grasses, chickweed (see label)	Iris, peony, ground covers (see label)	15	• apply to weed-free soil • best in cool, moist soil
Roundup (glyphosate)	POST (to weeds) Broad spectrum weed control (see label)	Prior to planting on all crops	9	• systemic, avoid valuable plants • apply to actively growing plants at susceptible stages
Princep Nine-T (simazine) Simadex, Simazine 480	PRE Various broadleaf weeds and annual grasses	Woody ornamentals and nursery stock (see label)	5	• apply to weed-free soil • repeated applications may leave soil residues that damage subsequent crops • use lower rate on low organic matter soils
Venture L (fluazifop)	POST Grass weeds (see label)	Outdoor ornamentals (see label)	1	• apply to actively growing grasses • do not cultivate for 5 days • test on a few plants for tolerance

PPI — preplant incorporated; PRE — preemergent; POST— postemergent (to the weeds)

12. Appendices

APPENDIX A. Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) Floriculture Advisory Staff

Wayne Brown
OMAFRA Greenhouse Floriculture Specialist
Vineland, Department of Plant Agriculture
University of Guelph
Tel: 905-562-4141, ext. 179
Fax: 905-562-3413
E-mail: wayne.brown@omafra.gov.on.ca

Graeme Murphy
OMAFRA Greenhouse Floriculture IPM Specialist
Vineland, Department of Plant Agriculture
University of Guelph
Tel: 905-562-4141, ext. 106
Fax: 905-562-3413
E-mail: graeme.murphy@omafra.gov.on.ca

A complete list of Ontario Ministry of Agriculture, Food and Rural Affairs advisory staff is available on the ministry website at *www.omafra.gov.on.ca/crops*.

Agricultural Information Contact Centre

Provides province-wide, toll-free technical and business information to commercial farms, agri-businesses and rural businesses.

1 Stone Rd. W.
Guelph, ON N1G 4Y2
Tel: 519-826-4047
Toll-free: 1-877-424-1300
Fax: 519-826-7610
E-mail: ag.info@omafra.gov.on.ca

Guelph – ServiceOntario
1 Stone Rd. W.
Guelph, ON N1G 4Y2
Tel: 519-826-3100 (Staff Directories)
Toll-free: 1-888-466-2372

APPENDIX B: Ontario Ministry of the Environment Pesticide Control Offices

REGION County	Address	Telephone/Fax
Central Region Toronto, Halton, Peel York, Durham	5775 Yonge St, 8th Floor Toronto, ON M2M 4J1	Tel: 416-326-3671 Toll-free: 1-800-810-8048 Fax: 416-325-6345
West-Central Region Haldimand-Norfolk, Niagara, Hamilton-Wentworth, Dufferin, Wellington, Waterloo, Brant	Ontario Government Building 119 King St. West, 12th Floor Hamilton, ON L8P 4Y7	Tel: 905-521-7667 Fax: 905-521-7820
Eastern Region Frontenac, Hastings, Lennox & Addington, Prince Edward, Leeds & Grenville, Prescott & Russell, Stormont/Dundas & Glengarry, Haliburton, Peterborough, Victoria, Northumberland, Renfrew, Ottawa-Carleton, Lanark, District of Nipissing (Townships of Airy, Murchison, Dickens, Lyell and Sabine)	133 Dalton Avenue, P.O. Box 820 Kingston, ON K7L 4X6	Tel: 613-549-5047 Toll-free: 1-800-267-0974 Fax: 613-548-6908
Southwestern Region Elgin, Middlesex, Oxford, Essex, Kent, Lambton, Bruce, Grey, Huron, Perth, Simcoe	733 Exeter Road London, ON N6E 1L3	Tel: 519-873-5041 Tel: 519-873-5048 Fax: 519-873-5020
Northern Region East Manitoulin, Nipissing, Parry Sound, Sudbury, Algoma East, Cochrane East, Muskoka	199 Larch Street, Ste 1101 Sudbury, ON P3E 5P9	Tel: 705-564-3237 Fax: 705-564-4180
Northern Region West Kenora, Rainy River, Thunder Bay, Algoma West, Cochrane West, Timmins	435 James St. S., Suite 331 Thunder Bay, ON P7E 6S7	Tel: 807-475-1205 Fax: 807-475-1745
Standards Development Branch	Pesticides Section 40 St. Clair Avenue West, 7th Floor Toronto, ON M4V 1M2	Tel: 416-327-5519 Fax: 416-327-2936
Approvals Branch	Pesticides Licensing 2 St. Clair Avenue West, 12A Floor Toronto, ON M4V 1L5	Tel: 416-314-8001 Fax: 416-314-8452

APPENDIX C. Tissue Testing and Accredited Soil Testing Laboratories in Ontario

The following labs are accredited to perform analyses on greenhouse media and nutrient solutions. Contact the lab for the listing of analytical tests available.

Company	Address		Contact
Agri-Food Laboratories 503 Imperial Road, Unit #1 Guelph, ON N1H 6T9	Tel: 519-837-1600 Toll-free: 1-800-265-7175 Fax: 519-837-1242	Website: *www.agtest.com* E-mail: lab@agtest.com	Dale Cowan Nora Wilson
Stratford Agri Analysis Inc. (A Daco Laboratories Ltd. Company) 1131 Erie Street, Box 760 Stratford, ON N5A 6W1	Tel: 519-273-4411 Toll-free: 1-800-323-9089 Fax: 519-273-4411	E-mail: saa@dacolabs.com	Dale Peters Keith Lemp

There is no official accreditation in Ontario for tissue analysis but all of the accredited soil testing labs are monitored for proficiency on tissue analyses.

APPENDIX D. Other Contacts

AGRICULTURE & AGRI-FOOD CANADA RESEARCH CENTRES

Eastern Cereals and Oilseeds Research Centre
960 Carling Avenue
Ottawa, ON K1A 0C6
Tel: 613-759-1952
Website: *http://res2agr.ca/ecorc/index_e.htm*

Greenhouse and Processing Crops Centre
2585 County Road 20
Harrow, ON N0R 1G0
Tel: 519-738-2251
Website: *http://res2.agr.ca/harrow/*

Southern Crop Protection and Food Research Centre
Website: *http://res2.agr.ca/london/pmrc/index_e.htm*
1391 Sandford Street
London, ON N5V 4T3
Tel: 519-457-1470

Vineland Research Farm
4902 Victoria Avenue North
Vineland, ON L0R 2E0
Tel: 905-562-4113

Delhi Research Farm
Box 186 Schafer Road
Delhi, ON N4B 2W9
Tel: 519-582-1950

CANADIAN FOOD INSPECTION AGENCY REGIONAL OFFICES (PLANT PROTECTION)

www.inspection.gc.ca/english/toce.shtml

Belleville
345 College Street East
Belleville, ON K8N 5S7
Tel: 613-969-3332

Brantford
Federal Building,
58 Dalhousie St., P.O. Box 637
Brantford, ON N3T 5P9
Tel: 519-753-3478

Hamilton
709 Main Street West, Suite 101
Hamilton, ON L8S 1A2
Tel: 905-570-8265

London
457 Richmond Street, Suite 404
London, ON N6A 3E3
Tel: 519-645-4021
Fax: 519-691-1315

Niagara Falls
RR#1, P.O. Box 7
Niagara Falls, ON L0S 1J0
Tel: 905-357-5981

Ottawa District
Room 8, 38 Auriga Dr,
Ottawa, ON K2E 8A5
Tel: 613-274-7374 ext 221

Toronto
1124 Finch Ave West, Unit 2
Downsview, ON M3J 2E2
Tel: 416-665-5055
Fax: 416-665-5069

UNIVERSITY OF GUELPH

Main Campus
Guelph, ON N1G 2W1
Tel: 519-824-4120
Website: *www.uoguelph.ca*

Alfred College
Alfred, ON K0B 1A0
Tel: 613-679-2218
Fax: 613-679-2423
Website: *www.alfredc.uoguelph.ca*

Kemptville College
Kemptville, ON K0G 1J0
Tel: 613-258-8336
Fax: 613-258-8384
Website: *www.kemptvillec.uoguelph.ca*

Ridgetown College
Ridgetown, ON N0P 2C0
Tel: 519-674-1500
Website: *www.ridgetownc.on.ca*

Department of Plant Agriculture
Web site: *www.plant.uoguelph.ca*

Department of Plant Agriculture, Guelph
50 Stone Road West,
Guelph, ON N1G 2WI
Tel: 519-824-4120 ext. 53391
Fax: 519-763-8933

Department of Plant Agriculture, Simcoe
1283 Blueline Road, Box 587
Simcoe, ON N3Y 4N5
Tel: 519-426-7127
Fax: 519-426-1225

Department of Plant Agriculture, Vineland
Box 7000, 4890 Victoria Avenue North
Vineland Station, ON L0R 2E0
Tel: 905-562-4141
Fax: 905-562-3413

Lab Services Division
Website: *www.uoguelph.ca/labserv/*

Pesticide and Trace Contaminants
P.O. Box 3650, 95 Stone Road West
Guelph, ON N1H 8J7
Tel: 519-767-6200

Pest Diagnostic Clinic
Tel: 519-767-6256

APPENDIX E. Diagnostic Service

Samples for disease diagnosis, insect or weed identification, nematode counts and *Verticillium* testing can be sent to:

Pest Diagnostic Clinic
Laboratory Services Division
University of Guelph
95 Stone Rd. W.
Guelph, ON N1H 8J7
Tel: 519-767-6256
Fax: 519-767-6240
E-mail: pdc@lsd.uoguelph.ca

Payment must accompany samples at the time of submission. Submission forms are available at *www.uoguelph.ca/pdc*.

Fee Schedule

To obtain information on the fee schedule, refer to *www.uoguelph.ca/pdc* or phone the Pest Diagnostic Clinic.

How to Sample for Nematodes

Soil

When to sample
Soil and root samples can be taken at any time of the year that the soil is not frozen. In Ontario, nematode soil population levels are generally at their highest in May and June and again in September and October.

How to sample soil
Use a soil sampling tube, trowel or narrow-bladed shovel to take samples. Sample soil to a depth of 20–25 cm (8–10 in.). If the soil is bare, remove the top 2 cm (1 in.) prior to sampling. A sample should consist of 10 or more subsamples combined. Mix well. Then take a sample of 0.5–1 L (1 pint–1 quart) from this. No one sample should represent more than 2.5 ha (6.25 ac). Mix subsamples in a clean pail or plastic bag.

Sampling pattern
If living crop plants are present in the sample area, take samples within the row and from the area of the feeder root zone (with trees, this is the drip line).

Number of subsamples
Based on the total area sampled:

500 m^2 (5,400 ft^2)	10 subsamples
500 m^2–0.5 ha (5,400 ft^2–1.25 ac)	25 subsamples
0.5 ha–2.5 ha (1.25–6.25 ac)	50 subsamples

Roots

From small plants, sample the entire root system plus adhering soil. For large plants, 10–20 g ($^1/_2$–1 oz.) dig fresh weight from the feeder root zone and submit.

Problem areas

Take soil and root samples from the margins of the problem area where the plants are still living. If possible, also take samples from healthy areas in the same field. If possible, take both soil and root samples from problem and healthy areas in the same field.

Sample handling

Soil samples

Place in plastic bags as soon as possible after collecting.

Root samples

Place in plastic bags and cover with moist soil from the sample area.

Storage

Store samples at 5°C–10°C (40°C–50°F) and do not expose them to direct sunlight or extreme heat or cold (freezing). *Only living nematodes can be counted. Accurate counts depend on proper handling of samples.*

Submitting Plant for Disease Diagnosis or Identification

Sample submission forms

Forms can be obtained from your local Ontario Ministry of Agriculture and Food office. Carefully fill in all of the categories on the form. In the space provided, draw the most obvious symptom and the pattern of the disease in the field. It is important to include the cropping history of the area for the past three years and this year's pesticide use records.

Choose a complete, representative sample showing early symptoms. Submit as much of the plant as is practical, including the root system or several plants showing a range of symptoms. If symptoms are general, collect the sample from an area where they are of intermediate severity. Completely dead material is usually inadequate for diagnosis.

With plant specimens submitted for identification, include at least a 20–25-cm sample of the top portion of the stem with lateral buds, leaves, flowers or fruits in identifiable condition. Wrap plants in newspaper and put in a plastic bag. Tie the root system off in a separate plastic bag to avoid drying out and contamination of the leaves by soil. Do not add moisture, as this encourages decay in transit. Cushion specimens and pack in a sturdy box to avoid damage during shipping. Avoid leaving specimens to bake or freeze in a vehicle or in a location where they could deteriorate.

Delivery

Deliver to the Pest Diagnostic Clinic as soon as possible by first class mail or by courier at the beginning of the week.

Submitting Insect Specimens for Identification

Collecting samples

Place dead, hard-bodied insects in vials or boxes and cushion with tissues or cotton. Place soft-bodied insects and caterpillars in vials containing alcohol. Do not use water, as this results in rot. Do not tape insects to paper or send them loose in an envelope.

Place live insects in a container with enough plant "food" to support them during transit. Be sure to write "live" on the outside of the container.

UNIVERSITY of GUELPH LABORATORY SERVICES

95 Stone Road West
Guelph, ON N1H 8J7
Tel: (519) 767-6256
Fax: (519) 767-6240
Web: www.uoguelph.ca/pdc

Pest Diagnostic Clinic

SAMPLE SUBMISSION FORM

LABORATORY USE ONLY: LS Form: SubP01/04/03

Rec'd: By: ____________ **Date Received:** ____________

Delivered By: ☐ **Mail** ☐ **Courier** ☐ **In-Person**

LS Sample No: ____________ **to** ____________

Payment Rec'd: $____________ **Receipt #:**____________

Submitted By:			Owner (if different from submitter):		
Business Name (if applicable):			Business Name (if applicable):		
Street:			Street:		
City:	Prov:	Postal Code:	City:	Prov:	Postal Code:
Tel: ( ) -	Fax: ( ) -		Tel: ( ) -	Fax: ( ) -	
Email:			Email:		

Unless otherwise indicated, report and invoice will be sent to submitter

Report to: ☐ Submitter ☐ Owner

Required Report Format: ☐ Fax ☐ E-Mail ☐ Mail

Invoice to: ☐ Submitter ☐ Owner Quotation #: __________

Purchase Order / U of G G/L code:____________________

Services Required: ☐ Nematode Count ☐ Nematode Count from Roots ☐ SCN Cyst & Egg Count ☐ Verticillium Count ☐ Plant Disease Diagnosis ☐ Insect Identification ☐ Plant Identification ☐ Triazine Resistance Test

Plant or Host Affected:		Cultivar/Variety:	Grower/Field sample #:
		Location of Plant (i.e. greenhouse, field, orchard, garden, etc.):	
Size of Planting:	% of Plants Affected:	Symptoms First Appeared in Past: ☐ Days ☐ Weeks ☐ Months ☐ Years	Degree of Injury: ☐ Severe ☐ Moderate ☐ Light
Cropping History:		Future Crop:	

Describe the problem in detail (i.e. symptoms, plant parts affected, distribution of symptoms):

Were chemicals applied? Please specify type of product(s) used and date(s) of application:

Additional comments and specific requests:

Additional Sheet(s) Attached: ☐

APPENDIX F. The Metric System

Metric Units

Linear Measures (length)

10 millimetres (mm) = 1 centimetre (cm)
100 centimetres (cm) = 1 metre (m)
1,000 metres = 1 kilometre (km)

Square Measures (area)

100 m × 100 m = 10,000 m^2 = 1 hectare (ha)
100 ha = 1 square kilometre (km^2)

Cubic Measures (volume)

Dry Measure

1,000 cubic millimetres (mm^3) = 1 cubic centimetre (cm^3)
1,000,000 cm^3 = 1 cubic metre (m^3)

Liquid Measure

1,000 millilitres (mL) = 1 litre (L)
100 L = 1 hectolitre (hL)

Weight-Volume Equivalents (for water)

(1.00 kg) 1,000 grams = 1 litre (1.00 L)
(0.50 kg) 500 g = 500 mL (0.50 L)
(0.10 kg) 100 g = 100 mL (0.10 L)
(0.01 kg) 10 g = 10 mL (0.01 L)
(0.001 kg) 1 g = 1 mL (0.001 L)

Weight Measures

1,000 milligrams (mg) = 1 gram (g)
1,000 g = 1 kilogram (kg)
1,000 kg = 1 tonne (t)
1 mg/kg = 1 part per million (ppm)

Dry–Liquid Equivalents

1 cm^3 = 1 mL
1 m^3 = 1000 L

Metric Conversions

5 mL = 1 tsp
15 mL = 1 tbsp
28.5 mL = 1 fl. oz.

Application Rate Conversations

Metric to Imperial (Approximate)

litres per hectare × 0.09 = gallons per acre
litres per hectare × 0.36 = quarts per acre
litres per hectare × 0.71 = pints per acre
millilitres per hectare × 0.015 = fluid ounces per acre
grams per hectare × 0.015 = ounces per acre
kilograms per hectare × 0.89 = pounds per acre
tonnes per hectare × 0.45 = tons per acre

Imperial to Metric (Approximate)

gallons per acre × 11.23 = litres per hectare (L/ha)
quarts per acre × 2.8 = litres per hectare (L/ha)
pints per acre × 1.4 = litres per hectare (L/ha)
fluid ounces per acre × 70 = millilitres per hectare (mL/ha)
tons per acre × 2.24 = tonnes per hectare (t/ha)
pounds per acre × 1.12 = kilograms per hectare (kg/ha)
ounces per acre × 70 = grams per hectare (g/ha)

Liquid Equivalents

Litres/Hectare — *Approximate Gallons/Acre*

50 L/ha = 5 gal./acre
100 L/ha = 10 gal./acre
150 L/ha = 15 gal./acre
200 L/ha = 20 gal./acre
250 L/ha = 25 gal./acre
300 L/ha = 30 gal./acre

Dry Weight Equivalents

Grams or Kilograms / Hectare — *Ounces or Pounds / Acre*

100 g/ha = 1½ oz./acre
200 g/ha = 3 oz./acre
300 g/ha = 4¼ oz./acre
500 g/ha = 7 oz./acre
700 g/ha = 10 oz./acre
1.10 kg/ha = 1 lb./acre
1.50 kg/ha = 1¼ lb./acre
2.00 kg/ha = 1¾ lb./acre
2.50 kg/ha = 2¼ lb./acre
3.25 kg/ha = 3 lb./acre
4.00 kg/ha = 3½ lb./acre
5.00 kg/ha = 4½ lb./acre
6.00 kg/ha = 5¼ lb./acre
7.50 kg/ha = 6¾ lb./acre
9.00 kg/ha = 8 lb./acre
11.00 kg/ha = 10 lb./acre
13.00 kg/ha = 11½ lb./acre
15.0 kg/ha = 13½ lb./acre

Conversion Tables — Metric to Imperial

Length

1 millimetre (mm) = 0.04 inch

1 centimetre (cm) = 0.40 inch

1 metre (m) = 39.40 inches

1 metre (m) = 3.28 feet

1 metre (m) = 1.09 yards

1 kilometre (km) = 0.62 mile

Area

1 square centimetre (cm^2) = 0.16 square inch

1 square metre (m^2) = 10.77 square feet

1 square metre (m^2) = 1.20 square yards

1 square kilometre (km^2) = 0.39 square mile

1 hectare (ha) = 107,636 square feet

1 hectare (ha) = 2.5 acres

Volume (dry)

1 cubic centimetre (cm^3) = 0.061 cubic inch

1 cubic metre (m^3) = 1.31 cubic yards

1 cubic metre (m^3) = 35.31 cubic feet

1,000 cubic metres (m^3) = 0.81 acre-foot

1 hectolitre (hL) = 2.8 bushels

Volume (liquid)

1 millilitre (mL) = 0.035 fluid ounce

1 litre (L) = 1.76 pints

1 litre (L) = 0.88 quart

1 litre (L) = 0.22 gallon (Imp.)

1 litre (L) = 0.26 gallon (U.S.)

Weight

1 gram (g) = 0.035 ounce

1 kilogram (kg) = 2.21 pounds

1 tonne (t) = 1.10 short tons

1 tonne (t) = 2,205 pounds

Pressure

1 kilopascal (kPa) = 0.15 pounds/in.^{2}

Speed

1 metre per second = 3.28 feet per second

1 metre per second = 2.24 miles per hour

1 kilometre per hour = 0.62 mile per hour

Temperature

°F = (°C × 9/5) + 32

Conversion Tables — Imperial to Metric

Length

1 inch = 2.54 cm

1 foot = 0.30 m

1 yard = 0.91 m

1 mile = 1.61 km

Area

1 square foot = 0.09 m^2

1 square yard = 0.84 m^2

1 acre = 0.40 ha

Volume (dry)

1 cubic yard = 0.76 m^3

1 bushel = 36.37 L

Volume (liquid)

1 fluid ounce (Imp.) = 28.41 mL

1 pint (Imp.) = 0.57 L

1 gallon (Imp.) = 4.55 L

1 gallon (U.S.) = 3.79 L

Weight

1 ounce = 28.35 g

1 pound = 453.6 g

1 ton = 0.91 tonne

Pressure

1 pound per square inch = 6.90 kPa

Temperature

°C = (°F − 32) × 5/9

Handy Metric Conversion Factor

litres per hectare × 0.4 = litres per acre

kilograms per hectare × 0.4 = kilograms per acre

Abbreviations

% = per cent (by weight)
ai = active ingredient
AP = agricultural powder
cm = centimetre
cm^2 = square centimetre
DG = dispersible granular
DF = dry flowable
DP = dispersible powder
E = emulsifiable
e.g. = for example
EC = emulsifiable concentrate
F = flowable
g = gram
Gr = granules, granular
ha = hectare
kg = kilogram
km/h = kilometres per hour
kPa = kilopascal
L = litre
m = metre
m^2 = square metre
mL = millilitre
mm = millimetre
m/s = metres per second
SC = sprayable concentrate
SP = soluble powder
t = tonne
W = wettable (powder)
WDG = water dispersible granular
WP = wettable powder

Notes

Notes

Emergency and First-Aid Procedures for Pesticide Poisoning

For a major spill, a theft or a fire involving a pesticide call the Ministry of the Environment at **1-800-268-6060.**

For pesticide poisonings and pesticide injuries call the **Poison Information Centre:**

Toronto	1-800-268-9017
Hearing Assistance (TTY)	1-877-750-2233

PREVENT ACCIDENTS

- **Read the label**. Follow all the precautions the label recommends. Read the First Aid section of the label BEFORE you begin to handle any pesticide.
- **Make sure that someone knows** what pesticides you are working with and where you are.
- **Keep a file of labels and product Material Safety Data Sheets (MSDS) for the pesticides you use**. Make sure everyone knows where to find this in case of an emergency.
- **Post emergency numbers near all telephones.**
- **Keep clean water, paper towels, extra gloves and clean coveralls close by** in case you spill pesticide on yourself.

If someone has been working with pesticides and you see any possible symptoms of pesticide poisoning or injury, take emergency action immediately.

IF AN ACCIDENT OR POISONING HAPPENS

- Protect yourself from injury first.
- Stop the exposure to the pesticide. Move the victim away from the contaminated area.
- Check the four basic facts — identify the pesticide, the quantity, the route of entry and time of exposure.
- Call an ambulance or the Poison Information Centre.
- Start first aid. This is **not** a substitute for professional medical help.
- **Provide the label, MSDS sheet or container to emergency personnel** at the scene — or take it with you to the hospital. Do not transport pesticide containers in the passenger compartment of the vehicle.

FIRST AID

If a pesticide comes in contact with skin:

- remove all contaminated clothing; wash skin thoroughly with lots of soap and warm water
- dry skin well and cover with clean clothing or other clean material.

If pesticide comes in contact with eyes:

- hold eyelids open; wash the eyes with clean running water for 15 minutes or more.

If pesticide was inhaled:

- move the victim to fresh air and loosen tight clothing
- give artificial respiration if the victim is not breathing.

Do not breathe in the exhaled air from the victim — you could also be poisoned.

If a pesticide was swallowed:

- **call the Poison Information Centre IMMEDIATELY.**

Emergency numbers are listed at the front of each Bell telephone directory.

For information, or to obtain copies of this or any other ministry publication please: call 1-888-466-2372 from within Ontario, 519-826-3700 from outside the province or OMAFRA's TTY line at 519-826-7402 for the hearing impaired, email your request to *products@omafra.gov.on.ca*, or visit OMAFRA's website at *www.omafra.gov.on.ca*.

A complete list of all OMAFRA products and services, and order forms, are available on the website. Orders can be faxed to 519-826-3633 or mailed to ServiceOntario, 1 Stone Road West, Guelph, Ontario N1G 4Y2.

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